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CONTRIBUTIONS
No. 18

INHERITANCE OF ENDOSPERM COLOR IN MAIZE

BY ORLAND E. WHITE

BROOKLYN, N. Y.
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INHERITANCE OF ENDOSPERM COLOR IN MAIZE[1]

ORLAND E. WHITE

Few of the many characters in plants and animals studied by geneticists during the last seventeen years are now to be regarded as inherited in simple fashion. As more detailed and extensive studies on the heredity of each type of character, once regarded as a simple unit, are made, the more various the facts and the more complex the interpretations have become. The present paper describes such an increase in complexity of fact and interpretation in the heredity of endosperm color in maize, which at the outset was regarded as a single allelomorphic pair consisting of yellow and white, but which at present involves possibly as many as four pairs of factors, one of which brings about a dominance of white.

As studied and interpreted by Correns (3, 4) and Lock (10) and others, yellow endosperm in maize is determined by the presence of a factor for yellow, in the absence of which, the endosperm remains white. Lock (10) found various degrees of yellow among the grains classified as yellow, but all were easily separated from the white, so that he regarded them as fluctuations of slight importance, and, in his interpretation, did not distinguish between them. He notes, however, that on the average, homozygote yellows are deeper colored than heterozygotes. Lock studied very large numbers of F_2, F_3, and F_4 generation hybrid plants from crosses of yellow and white endosperm varieties. Back-crosses of the yellow heterozygote with the recessive white homozygote were also made in large numbers. The numerical results are very slightly vitiated by the technique used, but the numbers are so large as to make the small error from this source, in this particular case, of comparatively slight importance. Lock's results are summarized in Table 1.

Further studies by East and Hayes (5, 7), Burtt-Davy (1) and others on these endosperm colors brought to light a more complex state of affairs, for they found two yellow endosperm "colors" in maize, each behaving, when crossed with non-yellow (white) endo-

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[1] Brooklyn Botanic Garden Contributions No. 18.

TABLE I

Cross	Yellow	White	Total	Ratios Act. Obt.	Ratios Theor. Exp.
Yellow heterozygote × white homozygote (F_2)	1,963	1,982	3,945	49.6 :50.4	50:50
Yellow heterozygote × pure white variety	26,792	26,751	53,543	50.03:49.97	50:50
White variety (homozygote) × yellow heterozygote	2,723	2,846	5,569	48 :52	50:50
Totals	31,478	31,579	63,057	49.6 :50.4	50:50
F_2 white segregate × pure white variety	59 all white ears				all
Yellow heterozygote (selfed)	16,592	5,681	22,273	74.5 :25.5	75:25

sperm varieties, as an independent allelomorphic pair. In the varieties studied by East and Hayes, the two yellows were indistinguishable except that ears in which both were present in homozygous condition were usually darker than ears homozygous for either one of the yellows alone. Apparently either of the yellows, even in a homozygous condition, could not be distinguished from the other, but, when both were present in crosses with non-yellow races, the F_2 ratio approximated 15 Y : 1 W. Designating the two factors as Y_1 and Y_2, the presence of either produced a similar effect. In some crosses, dominance of yellow was complete and heterozygotes were indistinguishable, while, in other crosses, as many as five shades of yellow were present among the F_2 progeny, each shade signifying a difference in factorial composition from darker to light in the following order: $Y_1Y_1Y_2Y_2$, $Y_1Y_1y_2y_2$ or $y_1y_1Y_2Y_2$, $Y_1y_1Y_2y_2$, $Y_1y_1Y_2Y_2$ or $Y_1Y_1y_2Y_2$, $Y_1y_1y_2y_2$ or $y_1y_1y_2Y_2$. In Table 17, p. 56 (7) East and Hayes refer to an F_2 population from white × yellow endosperm which gives only a 3Y:1W ratio, but two shades of yellow are distinguishable—a dark and light in the ratio of 1 : 2. This is interpreted as a 1 : 2 : 1 monohybrid ratio in which the heterozygote is easily distinguished, owing to imperfect dominance. The nature of the starch, whether soft (flour) or horny (corneous), also causes a variation in the intensity of the yellow endosperm color. From certain crosses, in a few cases, apparently white segregate seeds, when planted, gave either pure yellow or 3 Y : 1 W progeny.

East and Hayes's data are partially summarized in Table 2:

TABLE 2

Segregation of Endosperm Color in Maize

Cross	Yellow	White	Total	Ratios Act. Obt.	Ratios Theor. Exp.
F_2 generation of white × yellow or reciprocal or data on hybrid population of same character........	9,458	466	9,924	95.1: 4.9	93.8:6.2 (15:1)
F_2 generation of white × light yellow or reciprocal or data on hybrid population of same character.....	6,792	2,428	9,220	73.7:26.3	75:25
F_2 generation of white × dark yellow or reciprocal or data on hybrid population of same character....	2,376	766	3,142	75.7:24.3	75:25
F_2 generation of white × yellow.....	609 dark yellow:1,143 light yellow: 589 white				
Expected........................	585.2 dark yellow:1,170.4 light yellow: 585.2 white				

The varieties studied by Burtt-Davy (1) apparently consisted of two distinct yellow types—a dark and a light, each of which with its "opposite" represented an independent allelomorphic pair. The darker of these yellows gives a 1 : 2 : 1 ratio, while "the other (the paler) gives the ratio 9 : 3 : 3 : 1." The writer is at a loss to understand the meaning of the above quoted statement, unless the two yellows were crossed together and gave in addition to three types of yellow, whites in the ratio of 1 W : 15 Y. If each yellow is represented by an independent factor, crosses with white should give in each case in F_2 only 1 : 2 : 1 or 3 : 1 ratios. This pale yellow has sometimes been mistaken for a "dominant white." Burtt-Davy found ten shades of yellow in the F_3 seed generation from crossing yellows with whites. Further, Burtt-Davy (p. 172, 173, 177, 188) refers to a yellow endosperm color, which depends for its expression on the presence of two factors—a color factor and a pigment factor. In absence of either, the endosperm will be white, and by crossing two white races, each carrying one of the factors, the resulting progeny will all have yellow endosperm.

Emerson (8) obtained from F_2 populations of crosses of the orange yellow Queen's Golden with Black Mexican (white endosperm), two yellow endosperm colors (a dark and a pale) in addition to the expected orange and white endosperm segregates, and in F_3, some of the pale yellow segregates bred true, while others gave 3 pale yellow : 1 white.

Collins (2) reports a dominant white (albinistic) mutation in endosperm color. The mutation consisted of a single, wholly white ear which appeared in a field of a carefully selected strain of dark yellow dent with red cobs known as Gorham Yellow Dent.

The "albinistic" ear was fully matured, had white cobs, and the seeds when closely examined had a faint trace of yellow at the base, but would ordinarily be regarded as pure white. This white was evidently "dominant" over the Gorham Dent yellow, since the original mutant ear must have been in part, at least, cross-pollinated from the surrounding plants—all of which were Gorham Dent. The immediate descendants of this ear, either when selfed or cross-pollinated, consisted of both yellows and whites, the former greatly predominating. The yellows consisted of both dents and pale types, the former being the more numerous. Seeds of the three color types were grown. From 19 white seeds, 17 all white self-pollinated ears and two white tinged yellow ears were obtained. From 16 light yellow seeds were obtained 2 very light yellow ears, 11 ears with light yellow and white seeds approximating in many cases a 3 Y : 1 W ratio, 1 ear with dark yellow and white seeds approximating a 3 : 1 ratio, and 2 ears unclassified. Forty-nine dark yellow seeds produced 16 ears with yellow of varying shades, 22 ears with both yellow and white grains in the ratio of 3 : 1 (8,694 Y : 2,954 W), 4 ears with both yellow and white grains in the ratio of 15 Y : 1 W (2,548 Y : 177 W—theoretically expected 2,555 Y : 170 W), and seven ears with all shades from dark yellow to white. Crosses between a second generation progeny plant from the albinistic ear (presumably heterozygous for yellow and white) (no. 47) with two white seeded varieties of corn, in both cases gave ears with both white and yellow grains—the ratios approximating 1 : 1. Selfed yellows (44 seeds) from various ears of the first cross (no. 47 × White Dent) gave yellows and whites approximating a ratio of 3 Y : 1 W (44 ears with 16,351 Y : 5,184 W, theoretically expected 16,151 Y : 5,384 W). Selfed yellow seeds from the second cross (no. 47 × white Hopi) gave 2 ears with both yellow and white seeds, the yellow predominating and one "*pure white ear*." Seeds of the selfed pure white ear gave 5 pure white ears and 4 faint yellowish tinted white seeded ears. No data are given as to cob color in the case of the second appearance of a white endosperm mutation, nor in the case of the dozen or more pure white ears obtained in later generations. Since both the white cob and white endosperm appeared together as a single mutation, it would be interesting to know whether they were inherited together, and whether the white cob color was also dominant over the red from which it sprung. Owing to ratio discrepancies, and the occurrence of traces of yellow in descendants of seeds classed as *pure* white, Collins regards the segregation of yellow and white endosperm color as incomplete or imperfect. In other words, factor contamination has occurred, though, in general, Mendelian ratios were obtained. Interpreting his results as showing the presence of at least two factors for yellow color and perhaps more, Collins regards as both "violent" and unwarranted. East (6, p. 404–405) however, in reviewing this paper, interprets Collin's data as demonstrating the presence of two factors for yellow endosperm color, one of which is much less effective in producing the yellow color than the other. East discredits the mutative reversal of dominance interpretation, suggesting the appearance of the original wholly white ear as due to non-development of color brought about by abnormal environmental causes, such as, perhaps, the "accidental presence" of some metallic salt in the soil. This suppression of color development, East intimates, is not extremely rare in experimental corn cultures.

NEW DATA

The material consisted of an inbred strain of California Golden Pop with yellow endosperm and a strain of white endosperm maize obtained from Haage & Schmidt under the name of *Zea Caragua*.[2] The latter bred true to a white endosperm intermediate between flour and corneous in texture. A white endosperm variety of Hopi maize, isolated from seed obtained from G. N. Collins, was also used.

In classifying the colors of the F_2 and F_3 seeds, three methods were used—(1) each seed as classified on the ear, was picked off and transferred to a black velvet background and contrasted either with the parental varieties or with other pure white and yellow races; (2) most of the seeds were classified independently by the writer and his assistant Miss M. Mann; (3) both the writer and Miss Mann reclassified many of the F_2 and F_3 ears twice, first by re-examining both the yellow and white groupings of each ear and second by mixing the two color groups together again and reselecting. In each reclassification, the ratios resulting from previous classifications were unknown. These determinations were fairly accurate as demonstrated by the F_2 classification and its F_3 progeny. In some cases a photographic blue ray screen was used.

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[2] Described by Sturtevant (11). Apparently an old variety desseminated in Europe by Vilmorin.

F_1 GENERATION PROGENY

California Golden Pop pollinated by *Zea Caragua* gave uniformly white endosperm grains with perhaps the very faintest suggestion of yellow.[3] This cross was repeated six times with similar results. The reciprocal cross has not yet been obtained. Crosses of Golden Pop pollinated with white endosperm Hopi gave similar results.

F_2 GENERATION

Three independent classifications of the F_2 progeny from California Golden Pop × *Zea Caragua* are given in Table 3. The first three ears were classified with the aid of a photographic blue ray screen.

TABLE 3

Endosperm Color of F_2 Progeny of (Z 14×Z 21)

Progeny No.	1st Classif.		2d Classif.		3d Classif.		Total Grains
	White	Yellow	White	Yellow	White	Yellow	
(Z 14×Z 21)—1	254	82	Practically		—	—	336
(" ")—2	264	108	the same		—	—	372
(" ")—3	285	89	"	"	—	—	374
(" ")—4[4]	257	79	235	101	225	111	336
(" ")—5[4]	346	73	319	100	267	152	419
(" ")—6[4]	338	98	358	79	340	96	436
(" ")—7[4]	346	77	316	109	259	166	425
(" ")—8[4]	248	70	235	82	214	104	318
(" ")—25*a*	350	146	311	185	354	142	496
(" ")—25*b*	358	129	350	137	339	148	487
(" ")—26*a*	422	126	420	128	410	138	548
(" ")—26*b*[5]	494	109	483	121	472	132	604
(" ")—28	336	91	318	109	315	112	427
(" ")—29*b*	478	131	460	149	438	171	609
(" ")—30	390	143	406	127	388	145	533
(" ")—31	373	54	313	114	316	111	427
(" ")—32	332	104	332	104	331	105	436
(" ")—33	427	73	371	129	386	114	500
(" ")—34*a*	221	52	209	64	211	62	273
(" ")—35	309	93	295	107	280	122	402
(" ")—36	375	95	379	91	369	101	470
(" ")—37	338	97	328	107	282	153	435

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[3] The F_1 white endosperm of these seeds is indistinguishable from that of seeds of several of the well known smooth white seeded varieties of pop-corn, when compared with them. From data on non-guarded crosses referred to later, the reciprocal cross probably gives the same results, except the endosperm is opaque white instead of translucent white.

[4] Ears obtained from unbagged F_1 plants allowed to intercross with other F_1s of similar pedigree.

[5] One unclassified.

Owing to the increased experience, the third classification given in Table 3 is probably the most accurate. Assuming that it is, from a total of 9,663 progeny, 6,999 were classed as white and 2,664 as yellow. On the assumption of a one-factor difference between the two maize races with complete or practically complete dominance of the white color, the theoretically expected numbers would be 7,248 W : 2,416 Y (3 : 1). The deviation between the ratio actually obtained and that theoretically expected is 249. The yellow segregates were far from uniform in color, all shades from a dark yellow (not orange) to a very light lemon yellow were present on the same ear. Further, in some ears, the yellow was principally confined to the base of the grain, nearest the point of attachment. A few dark yellow grains were somewhat deeper colored than the yellow grand-parental California Pop, but this may be due to segregation of various factors that effect endosperm texture, as the dark yellow grains usually appear less translucent than those of the grand-parental Pop variety.

BACK CROSSES OF F_1 WITH Z 21 (THE DOMINANT WHITE ENDOSPERM PARENT)

(Z 14 × Z 21)–29a × Z 21......All white
(Z 14 × Z 21)–34b × Z 21......All white

These two ears, resulting from back crosses of the F_1 with the dominant endosperm parent, came from two F_1 plants which also produced two selfed ears (29*b* and 34*a* in Table 3). The back-crossed ears were uniform in seed color, the white being more opaque than in the endosperm of the F_1 grains. Nos. 29*b* and 34*a* gave typical F_2 ratios and the yellows were of several shades as in all the other ears with F_2 seeds.

F_3 GENERATION

From self-pollinated ears Nos. 1, 2 and 3 (Table 3) of the F_2 generation, approximately 1,000 plants with F_3 endosperm seeds were grown. Of these, 43 ears were self-pollinated, 27 of which came from F_2 seeds classed as white, and 16 from F_2 seeds classed as yellow. Nine of the white seeds gave all white F_3 progeny, while 19 gave both white and yellow grains approximating the ratio of 3 W : 1 Y (Table 4). The 16 F_2 seeds classed as yellows gave 14 all yellow ears, and 3 ears with both white and yellow seeds approximating the ratio of 3 W : 1 Y.

TABLE 4

F_3 Progeny of White-Seeded F_2 Heterozygotes (*Z* 14×*Z* 21)

Plant No.	White	Yellow	Total No Grains
1 W—63	269	55	324
1 W—89	294	98	392
1 W—90	119	38	157
1 W—91*a*	277	122	399
1 W—93	364	88	452
1 W—98	233	74	307
1 W—99	298	108	406
1 W—101	298	140	438
2 W—66	309	75	384
3 W—43*a*	113	48	161
3 W—43*b*	190	90	280
3 W—48	143	70	213
3 W—49	119	39	158
3 W—52	343	104	447
3 W—53	216	56	272
3 W—56	59	22	81
3 W—57	417	72	489
2 Y—77*a*[6]	212	78	290
2 Y—77*b*[6]	245	81	326
2 Y—84[6]	185	47	232
Total actually obtained	4,703	1,505	6,208
Total theoretically expected	4,656	1,552	6,208

Both yellow and white endosperm colors varied markedly in this generation. In the case of white endosperm, the differences were largely due to segregation of factors affecting the texture and degree of translucency and opaqueness. Many ears had opaque caps, while the remainder of the endosperm was corneous. In such cases, the yellow was most apparent in the corneous region. Translucent whites such as one finds among popcorn varieties always appear slightly yellow when contrasted with opaque whites such as are found among the dent and wax varieties. No selfed ears were obtained of a deeper yellow color than that in the California Pop ancestor. The all yellow ears were of at least three distinguishable types: (1) a very light translucent lemon yellow, (2) a yellow as dark as the ancestral yellow and (3) a yellow with opaque whitish caps.

UNBAGGED EARS OF Z 14 AND Z 21

Unbagged ears on plants of Z 14 grown close to varieties with deep yellow or orange endosperm color invariably have a large number of dark yellow or orange grains, from which the dominance of these yellows over that of Z 14 (California Pop) is to be inferred, as bagged ears are always of a uniform medium yellow.

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[6] F_2 seeds probably wrongly classed as having yellow endosperm.

Unbagged ears of Z 21 (*Zea Caragua*) on plants grown under conditions similar to those mentioned for Z 14 have never been found in my cultures with yellow grains. Further, cultures of Z 21 grown alongside of F_1 and F_2 generation hybrids (Z 14 × Z 21) have always produced (in my experience) only white ears. The Z 21 cultures bloomed at about the same time as many of the hybrids, so that the difference in flowering time would not account for the absence of yellow grains.

INTERPRETATION

In the light of the preceding data, endosperm color differences between Z 14 (California Pop) and Z 21 (*Z. Caragua*) may be regarded as due to the presence and absence of a single factor A. The presence of A prevents the development of the yellow color, when the factors for yellow pigment are present, and gives no indication of its presence in a variety from which these factors are absent. In the absence of A, a given variety may be either yellow or white. In respect to this factor A, then, and a single factor for yellow pigment, varieties of corn may be of four kinds:

(1) AAYY (white endosperm)
(2) AAyy (white ")
(3) aaYY (yellow ")
(4) aayy (white ")

Crossed with each other, these should give:

Cross	F_1	F_2
1(W)×2(W)	white (AAYy)	all white
1(W)×3(Y)	white (AaYY)	3 W:1 Y
1(W)×4(W)	white (AaYy)	13 W:3 Y
2(W)×3(Y)	white (AaYy)	13 W:3 Y
2(W)×4(W)	white (Aayy)	all white
3(Y)×4(W)	yellow (aaYy)	3 Y:1 W

So far as the data on Z 14 × Z 21 are concerned, California Golden Pop would be represented on the above scheme as aaYY, while the formula AAYY would be the only one applicable to Z 21 (*Z. Caragua*). All of the common white endosperm varieties of corn which are wholly or partially recessive to yellow endosperm color have the formula aayy, neither the suppression nor the pigment factor being present.

First generation (F_1) progeny from crosses between whites such as 1 × 4, or whites and yellows such as 2 × 3, should give, when backcrossed with white endosperm aayy (4) plants, white and yellow endosperm seeds in the ratio of 3 W : 1 Y. In other words, two whites crossed together in F_1 give a certain proportion of yellows. The obtaining of such results in partially worked out experiments on heredity of endosperm color, in which it was taken for granted that white endosperm color was always recessive, might be temporarily interpreted as due to the presence of a color factor in a heterozygous condition in one of the races experimented with. Perhaps Burtt-Davy's statements regarding the presence of a color factor for endosperm (1, pp. 172, 173, 177) resulted from an experiment of this type. I have not had access to papers with the data on which these statements are based.

The preceding discussion assumes only one factor for yellow endosperm pigment, whereas East and Hayes, Collins and Burtt-Davy have each found at least two such factors. Further, Emerson and East (9, p. 11) suggest that orange endosperm color, such as is characteristic of Queen's Golden Pop, Tom Thumb Pop, Yardstick and some Chinese varieties (much intensified), is due possibly to the presence of a color intensifying factor. The F_2 and F_3 data on crosses of Z 14 × Z 21 show the presence of other color modifying factors, especially one which dilutes ordinary yellow to a very pale lemon color. Other investigators have also obtained this type.

SUMMARY

1. Crosses of a yellow endosperm variety of maize (California Golden Pop) with a white endosperm variety (*Z. Caragua*) gave uniformly white progeny in F_1 and a ratio approximating 3 W : 1 Y in F_2. The F_2 generation white grains, when planted, gave either all white F_2 generation progeny or a mixture of white and yellow grains approximating a ratio of 3 W : 1 Y. The F_2 yellow grains, except in two cases, produced all yellow F_3 self-pollinated ears. The yellow grains in both the F_2 and F_3 generations varied considerably, and, in F_3, ears wholly of *very* light lemon yellow grains were obtained. Unprotected ears of Z 21 in close proximity to varieties and hybrids having yellow endosperm always gave wholly white endosperm ears.

2. These results are interpreted as mainly due to the presence and absence of an endosperm color suppression factor A. A factor Y for yellow pigment is present in both races studied. *Zea Caragua* (Z 21) is to be regarded as homozygous for both A and Y, while California Golden Pop (Z 14) is homozygous for the presence of Y and the absence of A.

3. The segregation of other endosperm factors, such as those for flint and floury texture, opaque caps, etc., also modified the endosperm color expressions.

4. Including the suppression factor A, at least three and possibly five pairs of factors are primarily responsible for endosperm color in maize.

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17. *Endophyllum-like rusts of Porto Rico.* 8 pages, 3 plates. 1917.

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CONTRIBUTIONS
No. 20

INHERITANCE STUDIES IN PISUM

III. THE INHERITANCE OF HEIGHT IN PEAS

BY ORLAND E. WHITE

BROOKLYN, N. Y.
1918

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INHERITANCE STUDIES IN PISUM. III. THE INHERITANCE OF HEIGHT IN PEAS*

BY ORLAND E. WHITE

Brooklyn Botanic Garden

As regards height, varieties of peas were classified by Mendel ('66) as either tall or dwarf. When these two types were crossed, the F_1 generation was either as tall or taller than the tall parent. The F_2 generation consisted of approximately 3 tall : 1 dwarf (actual proportions 787 tall : 277 dwarf, or 2.84 : 1). All of the dwarf plants and approximately one third of the tall (28 out of 100) bred true in F_3, while the remaining 72 F_2 talls gave both talls and dwarfs in the ratio of 3 : 1. These results were interpreted as demonstrating a one-factor difference between tall and dwarf varieties of peas.

However, Bateson ('05), Keeble and Pellew ('10), Lock ('05), and others found the inheritance of height in certain cases to be more complex than indicated by Mendel. A class more or less intermediate in height between dwarfs such as Nott's Excelsior and Little Marvel and such talls as Scotch Beauty, Champion of England, and Späte Gold was recognized, to which the name half-dwarf was applied. Such varieties as First of All, Velocity, and Express are excellent examples of this class. Bateson ('05) says half-dwarfs are easily distinguished from talls, and lays particular emphasis on the zigzag growth of the stem as a marked characteristic of this group. If all varieties ranging in height from 3.5 to 4 or 4.5 feet are to be regarded as half-dwarfs, the above statement regarding zigzag growth, in the writer's experience, is only true of one group of half-dwarfs and these have short internodes, as noted later. Evidently Bateson's half-dwarfs are all of this type, but those of Keeble and Pellew ('10) and othe belong to at least two types.

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* Brooklyn Botanic Garden Contributions No. 20. These studies on the genetics of *Pisum* are carried on in collaboration with the Office of Forage Crop Investigations and the Office of Horticultural and Pomological Investigations, U. S. Department of Agriculture. For other titles of this series, see "Literature Cited."

Crosses between talls and half-dwarfs gave all tall in F_1 an approximately 3 talls : 1 half-dwarf in F_2 in some cases (Tsche mak, '02), while in other cases talls, half-dwarfs, and true dwar have appeared in F_2 (Bateson, '05, '09, p. 19). Half-dwarfs wit long internodes crossed with half-dwarfs with short internod gave talls with long internodes in F_1 and approximately 9 talls : half-dwarfs (short internodes) : 3 half-dwarfs (long internodes) : dwarf in F_2. The results actually obtained by Keeble and Pelle ('10) were 114 : 33 : 32 : 13—expected 108 : 36 : 36 : 12.

Notes taken by the writer for several years on the height, internode length, and internode number (per plant) of over 200 varieties of peas, grown under similar soil and climatic conditions, indicate a still greater complexity as regards the inheritance and classification of height in varieties of this genus.

For example, tall varieties (over 4.5 feet) may be divided into at least three distinct groups. One type of tall pea has 40 to 60 long internodes (Scotch Beauty, Späte Gold). Another type has 20 to 40 long internodes (Mammut, Goldkönig, White-Eyed Marrowfat). The internodes of each of these types average twice or more the length of the short internodes of the dwarfs. The third type of tall pea varieties is illustrated by Haage and Schmidt's "Graue Reisen Schnabel" which has 21 to 30 very long internodes. Variation in height and internode number among plants of the same true breeding variety is due largely to differences in environment. The absence of the factor for normal stem ($\underset{\smile}{Fa}$), causing fasciation, also brings about a shortening of the internodes. Other types of talls doubtless exist, but the writer's studies have not been detailed enough as yet to recognize them.

Crosses between the three types of talls, so far as they have been made, give in F_1 and F_2 all talls, but talls of different types. Large number of internodes is usually dominant over the low-number types. Sufficient data, as yet, are not available to determine the relation of these types in terms of factorial differences. Each type of tall undoubtedly represents a separate and distinct mutation.

As in the case of the tall-growing varieties of peas, the so-called

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"half-dwarfs" can be separated into at least two genetic types. One of these is illustrated by the examples of half-dwarf already mentioned—Velocity, First of All, and Express. These have long internodes, similar to the 40–60 and 20–40 long internode talls, but fewer in number, ranging between 10–20. The other type of half-dwarf has short internodes, similar to the short internodes of the true dwarfs. This type is illustrated by the variety Dwarf Gray Sugar, with internodes ranging in number from 20 to 40. The variety Autocrat, as studied by Keeble and Pellew ('10), probably also belongs in this category.

Half-dwarfs with long internodes crossed with short internode half-dwarfs give long internode talls in F_1 and long internode talls, long internode half-dwarfs, short internode half-dwarfs, and true dwarfs, approximating a 9 : 3 : 3 : 1 ratio in F_2. Similar results from such a cross, so far as the writer can judge, have been obtained by Keeble and Pellew ('10), although they have given them a somewhat different interpretation (see also Lock, '05). Half-dwarfs of each type crossed with similar half-dwarfs, as expected, breed true in F_1, F_2 and later generations. Half-dwarfs of the short internode type crossed with the 20–40 long internode tall type give in F_1 talls with long internodes, which in F_2 produce a population approximating 3 talls with long internodes : 1 half-dwarf with short internodes. The difference in height between such talls and such half-dwarfs is due largely to internode length, the number of internodes in each type being approximately the same. Half-dwarfs with long internodes crossed with talls with long internodes (20–40 type) give talls in F_1 and populations approximating 3 talls : 1 half-dwarf in F_2, both, of course, with long internodes, the difference between them in this case being due to internode number.

True dwarfs (6 inches to 3.5 feet high) in peas all have short internodes, ranging f om 8 to 20 in number. Laxtonian, Nott's Excelsior, and several French varieties obtained through the courtesy of Phillipe Vilmorin are excellent examples. When crossed with the various types of talls, the F_1 generation always consists of talls with long internodes, although large number of internodes may not be completely dominant over small number of internodes in certain cases, e. g., Pois nain à châssis, très hâtif crossed with Wachs Schwert (40–60 internodes tall). In such crosses, the F_1 generation is to be regarded as intermediate, so far as the gross character height is concerned, although this intermediate condition is brought about through incomplete dominance of high over low internode number. Tschermak ('01) also mentions obtaining intermediates in F_1, as regards height, from crosses of talls and dwarfs, though he says nothing about internode number or length. The F_2 generation from tall × dwarf or its reciprocal consists of four classes—talls with long internodes, half-dwarfs with either long or short internodes, and true dwarfs. These approximate a 9 : 3 : 3 : 1 ratio as in the case of short internode half-dwarf × long internode half-dwarf. Laxton ('06) obtained practically these same results. This is the cross usually

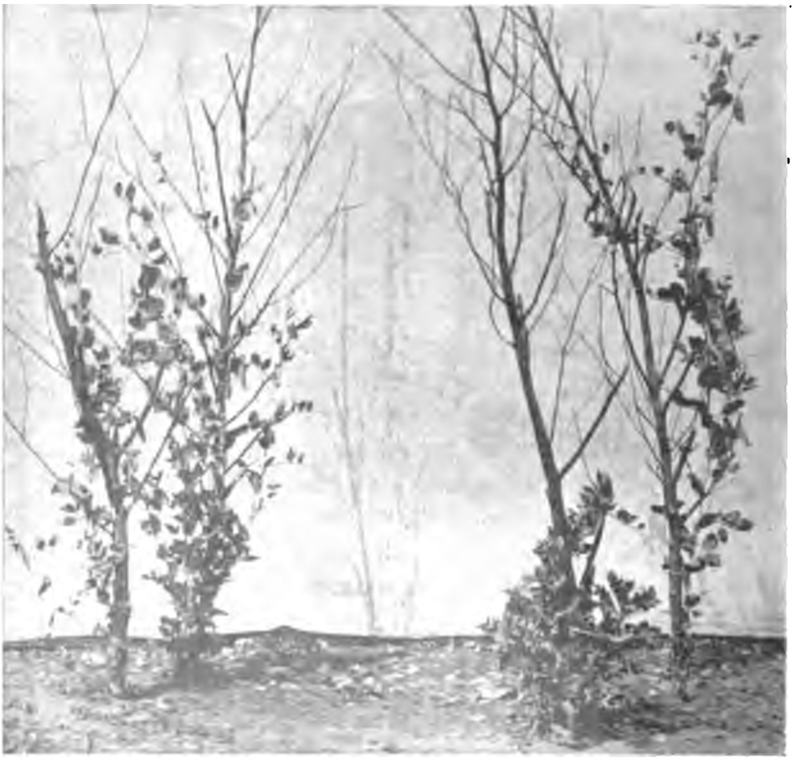

FIG. 1. F_2 generation tall and dwarf segregates from cross of tall × dwarf. Photo from cultures of E. M. East.

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made to illustrate the inheritance of height and probably the one made by Mendel for the same object. What is usually meant by geneticists, so far as the writer can learn, when discussing inheritance of height in peas, is really the inheritance of difference in internode length. Hence all short internode varieties or segregates, irrespective of actual height or number of internodes, are classed as dwarfs, while all long internode varieties or segregates, irrespective of number of internodes, are classed as talls. Classified in such a manner, the F_2 population from such a cross as described above would have approximately 3 tall (long internodes) : 1 dwarf (all short internodes). The long internode half-dwarfs would be called talls, while the half-dwarfs with short internodes would be called dwarfs (see Bateson *et al.*, '05; Lock, '05, '08; Laxton, '06).

Crosses between half-dwarfs with long internodes and true dwarfs gave half-dwarfs in F_1 and approximately 3 half-dwarf (long internodes) : 1 dwarf (short internodes) in F_2 in the writer's experiments. Bateson ('05) commonly obtained intermediates in F_1 from crosses between half-dwarfs (presumably short internodes) and dwarfs.

The simplest interpretation of the above data involves the presence and absence of at least five genetic factors for height, two of which primarily determine the differences in internode length and three of which are largely responsible for the hereditary differences in number of internodes. These with their expression may be represented as follows:

Le = long internodes
Le$_1$ = very long internodes
T = 20–40 internodes
T$_1$ = 40–60 internodes
T$_2$ = 20–30 internodes

Absences

le = short internodes
t = 10–20 internodes

Le and T have been referred to in previous numbers of this series (White, '17 a and b), Le being the factor isolated by Mendel and confirmed by many later workers. T is referred to by Keeble and Pellew ('**10**) as the factor for robust stems, but in the writer's interpretation of their results, it determines the difference in internode number.

On the above interpretation, the factorial composition of the three classes of talls would be:

(1) LeT = 20–40 long internodes.
(2) LeT_1 = 40–60 long internodes.
(3) Le_1T_2 = 20–30 very long internodes.

The factorial composition of the half-dwarfs would be:

(4) Let = 10–20 long internodes.
(5) leT = 20–40 short internodes.

The true dwarfs on this scheme would represent the absences of Le and T or (6) let.

Sufficient data have not yet been accumulated to determine in any detail the relations of these factors to each other except in the case of Le and T. Varieties with formula (1) crossed with (4) should and do give all long internode talls in F_1 and talls and half-dwarfs (long internode) in F_2. Combination (1) × (5) gives long internode talls in F_1 and approximately 3 talls (long internodes) : 1 half-dwarf (short internodes) in F_2. Combination (1) × (6) gives all long internode talls in F_1 and an F_2 population approximating 9 tall (l.i.) : 3 hd. (l.i.) : 3 hd. (s.i.) : 1 dwarf (s.i.). The two half-dwarf types, (4), (5) crossed with each other give all long internode talls in F_1, but an F_2 population similar to (1) × (6). Half-dwarf varieties (5) × dwarfs give intermediates in F_1 in some cases. The writer has no data on this cross as yet. Half-dwarf varieties with the formula Let (4) crossed with dwarfs (6) give all long internode half-dwarfs in F_1, and approximately 3 half-dwarfs : 1 dwarf in F_2.

Critics of Mendelian methods and conceptions will say again, as the above results are noted, "another unit-character has been split up." But the writer wishes to emphasize that with the same genetic pea material that Mendel and others have used to obtain the F_2 ratio of 3 talls : 1 dwarf, the same results will still be secured. The difference in interpretation has come from more detailed studies and the inheritance of height in peas has become complex only because of studies on new or distinctly different material, the characters of which, there is reason to believe, are due to distinct mutations.

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A large series of crosses involving height is in progress, and the data from these will be published in detail.

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This series consists of papers originally published in botanical or other periodicals, re-issued as "separates" without change of paging, and numbered consecutively. It includes occasional papers, as well as those embodying the results of research done at the Brooklyn Botanic Garden, or by members of its staff and students. Twenty-five numbers constitute one volume. Offered in exchange, or for sale at 25 cents a number; $5.00 a volume.

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CONTRIBUTIONS
No. 24

PLANTS AND ANIMALS OF MOUNT MARCY, NEW YORK

BY

CHARLES C. ADAMS, GEORGE P. BURNS, T. L. HANKINSON, BARRINGTON MOORE, AND NORMAN TAYLOR

BROOKLYN, N. Y.
1920

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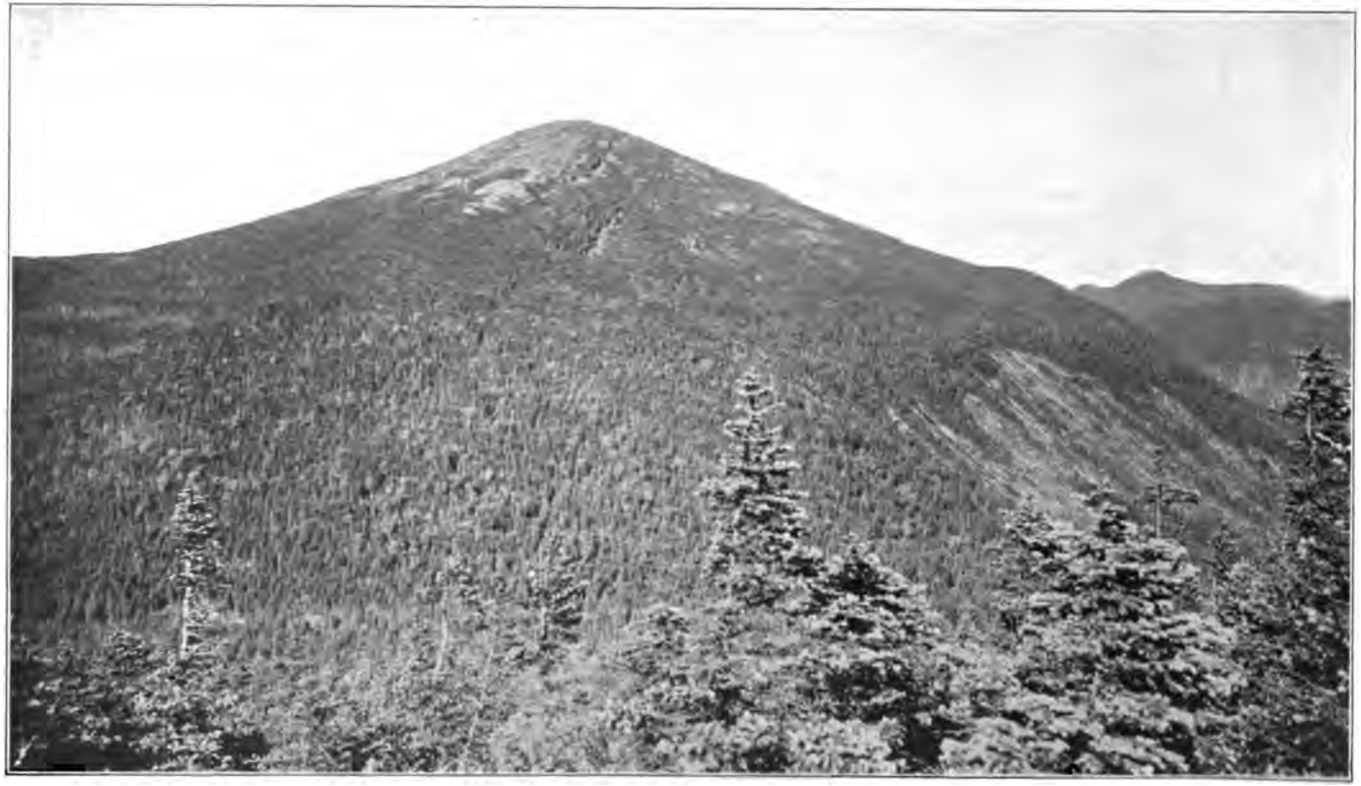

Frontispiece

By courtesy of the New York State Conservation Commission

Mount Marcy looking north from Mt. Skylight.

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PLANTS AND ANIMALS OF MOUNT MARCY, NEW YORK,
PART I

CHARLES C. ADAMS, GEORGE P. BURNS, T. L. HANKINSON, BARRINGTON MOORE, AND NORMAN TAYLOR[1]

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I. THE PROBLEM

The purpose of the present investigation was to bring to bear upon the problem of timber line on mountains the methods of study and knowledge of botanists, zoologists, and foresters in order to learn more of the relation of plants and animals to their environment. Timber line gives a comparatively sharp line of demarkation between different habitats, which can here be readily contrasted; also the factors of the environment causing this differentiation of habitats can be studied to advantage along the line where their influence is so marked.[2] The severity of the conditions to which organisms are subjected above timber line gives a splendid opportunity for studying the effects produced by the environment upon the plants and animals which have been able to withstand these conditions.[3] Furthermore it is necessary to consider organisms in relation to their past history, and the zone above timber line is a promising place for investigations on post-glacial migration.[4] Hence timber line on Mt. Marcy in the Adirondack Mountains of New York was chosen as a favorable locality for this cooperative study. The elevation of Mt. Marcy is 5,344 feet, the highest of any point in New York State.

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[1] Members of the Committee on Cooperation of the Ecological Society of America, chairman Barrington Moore. The institutions cooperating and authors representing them were: the Brooklyn Botanic Garden (Taylor), Roosevelt Wild Life Forest Experiment Station of the New York State College of Forestry at Syracuse (Adams and Hankinson), Vermont Agricultural Experiment Station (Burns). Valuable assistance in the field arrangements, with the Ausable Club as a base, was rendered by Mr. Alfred T. White, chairman of the Governing Committee of the Brooklyn Botanic Garden.

Observation and correlation were largely used in this investigation; instrumental records over a brief period were also secured for air temperature, soil temperature, evaporation, and solar radiation. These records, though insufficient for absolute comparisons, yet have a distinct relative value in showing differences between critical points in the vegetative covering of the mountain.

DEFINITION OF TIMBER LINE USED IN THIS STUDY.—There is no *absolute tree line* on Mount Marcy, since stunted trees grow in patches practically up to the summit. But there is what may be called a *timber line,* that is a line at which the forest cover stops, giving place to open vegetation with clumps of stunted trees in the depressions. *For the purpose of this study the timber line is considered as the beginning of alpine vegetation except in ravines and other depressions. Characteristic alpine plants of Mt. Marcy are Empetrum nigrum, Rhododendron lapponicum, Diapensia lapponica, Solidago Cutleri, and Vaccinium caespitsum.* The timber line as above defined occurs at between 4,800 and 4,900 feet, mostly near 4,900 feet, and, where not interfered with by ravines and slides, extends around the mountain with remarkable regularity. There is no sharp distinction between north-facing and south-facing slopes as in the mountains of the West, the absence of this contrast in the Adirondacks probably being due to the abundant rainfall which masks the differences in insolation.[5] Ravines extend up the mountain carrying the forest in a continuous body above the timber line. These ravines are sometimes so wide as to create the impression that solid timber extends above 4,900 feet. Yet even here a difference seems to occur at an elevation of between 4,800 and 4,900 feet, for at about 4,890 feet the trees become considerably shorter and more stunted. Looking from above at one of these ravines, the change in the character of the trees at timber line can be clearly seen.

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[2] Much has been written on the environment above timber line. For a brief discussion see C. H. Shaw's "Vegetation and altitude," Plant World, Vol. 12, No. 3. pp. 63–64, 1909, and "Causes of timber line on Mountains," Plant World, Vol. 12, No. 8, pp. 169–181, 1909.

[3] See paper on "Anatomical reduction in some Alpine plants," by C. C. Forsaith, in this issue for an interesting piece of work on this subject.

[4] Adams, Charles C. "Postglacial origin and migrations of life of Northeastern United States," Jour. Geography, Vol. 1, No. 7, pp. 303–310, 1902.

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II. The Region

Mount Marcy.—Mount Marcy lies in the eastern Adirondacks about 25 miles west of Lake Champlain. The mountain in profile is a low cone, with the upper few hundred feet forming a low dome. A general view of the south slope of the mountain, from Mount Skylight, is shown in the frontispiece, and a view of the upper part of the north slope, mainly above timber line, is shown in figure 1. The eastern and southeastern sides are more precipitous.

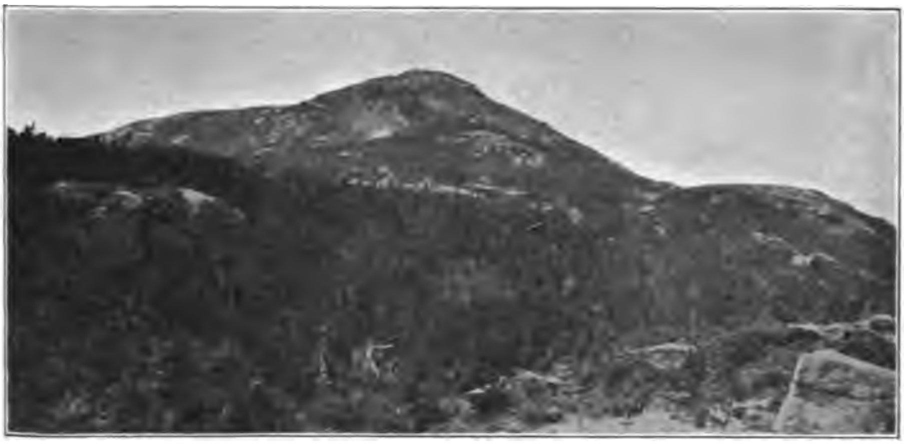

Fig. 1. North slope of Mt. Marcy from 4,850 feet elevation. Just below the summit on the left is the cirque containing a snowdrift; photographed June 5, 1919.

The conspicuous topographic features of the mountain above timber line are, ecologically considered, its isolation, its relatively small area and its relatively uniform relief. The isolation gives exposure on all sides. The domed surface favors rapid drainage, and the elevation into the cloud zone favors precipitation. There is a sphagnum bog on the northeast slope at about 5,000 feet, and a well-defined cirque (fig. 1) on the same slope at an elevation of 5,250 feet, later described and illustrated as the "Dwarf birch meadow." On the southwestern slope is a large ravine, which reaches to near the top of the mountain. The southeastern and eastern slopes are more

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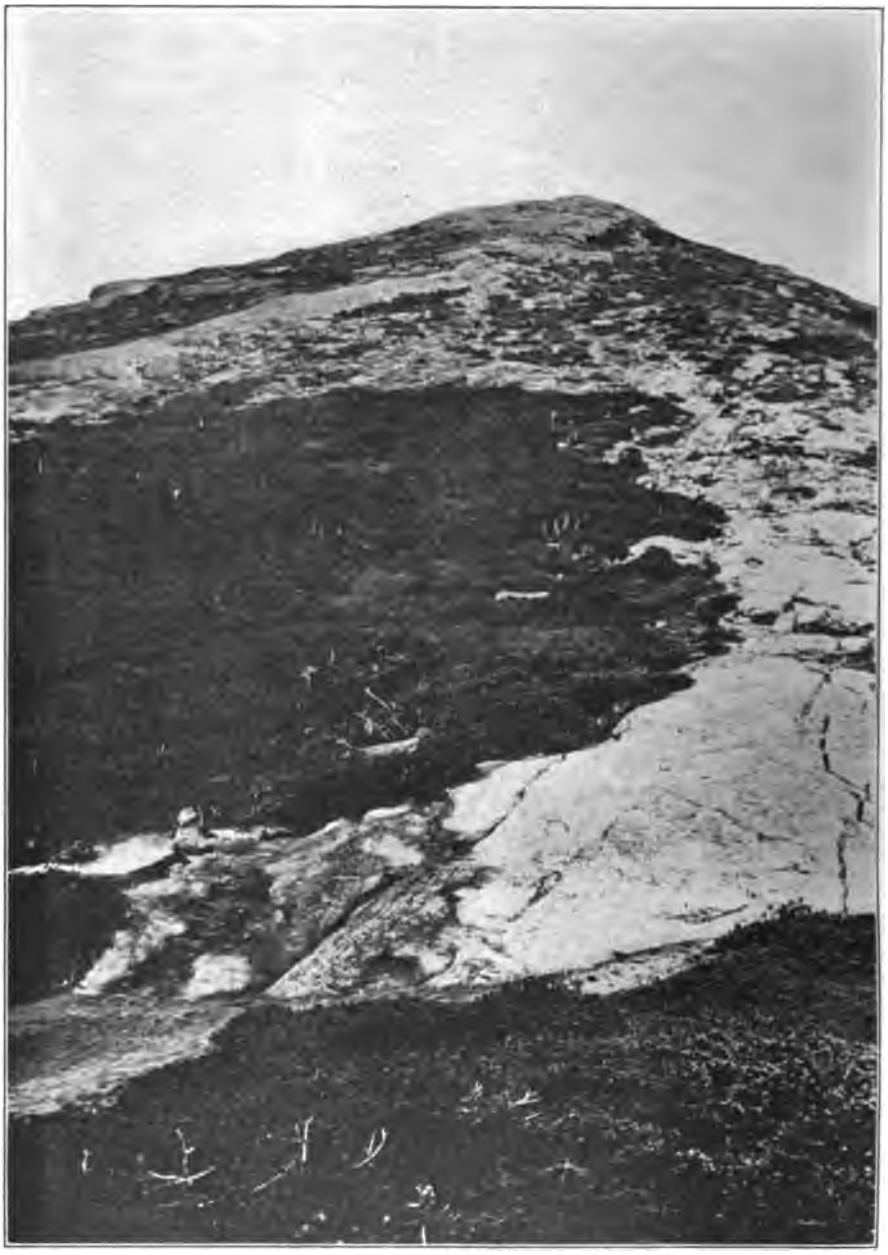
[5] Measurements of the rate of drying of the forest floor on north and south slopes are given by S. B. Show in his "Climate and forest fires in northern California." Journal of Forestry, Vol. 17, No. 8, pp. 965–979, 1919. Even greater contrasts are found in the Southern Sierras and in Arizona and New Mexico.



By courtesy of the New York State Conservation Commission.

FIG. 2. Southern trail slope of Mt. Marcy above timber line from 5,000 feet elevation. Stunted balsam fir in a depression in the foreground.

precipitous. The southern trail slope (fig. 2) contains much loose, bare rock and has the appearance of active snow slides. The vegetation below, to the southeast, supports this inference by the injury shown on the stunted balsams. The upper slopes are more stabilized, and when not bare rock or cut by rock and ice slides, are usually clothed with low vegetation, such as shown in figure 3. The cirque is in the lee of the mountain top and is located where snow would be expected to accumulate on account of the prevailing winter winds. This basin has diversified the alpine habitat by making conditions favorable for one of the alpine meadows, while joints or faults are apparently the cause of the formation of the meadows on the southeastern slopes. The rounded dome of the remainder of the mountain-top gives enough stability to the substratum to allow a few alpine meadows to develop.

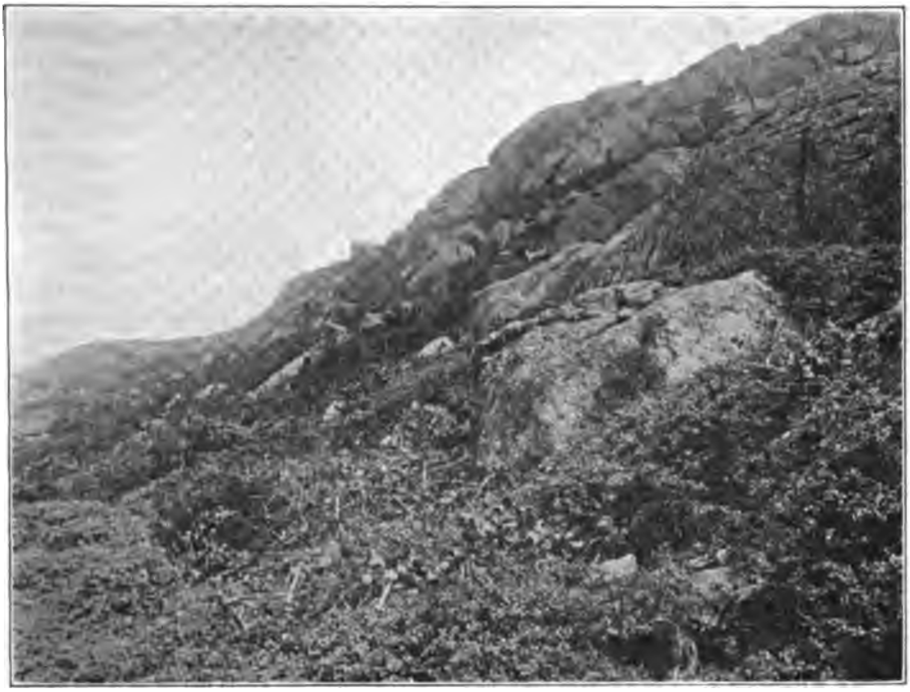


FIG. 3. Upper slopes of Mt. Marcy, showing alpine vegetation with stunted balsam firs in the sheltered spots.

TOPOGRAPHIC AND GEOLOGIC RELATIONS.—The culminating mountain peaks of eastern North America are Mount Mitchell, in the Southern Appalachians, with an elevation of 6,711 feet, Mount Washington, of the White Mountains (6,279 feet), and Mount Marcy or Tahawas (Indian for "Cloud-Splitter") of the Adirondacks, with an altitude of 5,344 feet. The topographic features of the Adirondacks may be summarized as follows:

The Adirondack region is a plateau formed by the uplifting of a peneplain, which now stands at an elevation of about 2,000 feet. Upon this dissected, tilted and much fractured upland arise, in the eastern part, the highest mountains of the Adirondacks. These were probably, in part, monadnocks upon this peneplain before it was elevated. The primary relief of the region is due to the partial development, from this plateau by erosion, of a later lower peneplain, in the main below 2,000 feet, combined with tilting and extensive faulting of mountain blocks, and to cutting and filling by glacial ice and waters. The postglacial changes are relatively slight, including a depression of the region, a re-elevation, the cutting of stream gorges, and the filling of depressions by inwash and organic debris.

The geological history of Mount Marcy, as a part of the Adirondacks, is wonderfully interesting, and certain phases are ecologically significant today. The region is one of the oldest mountain forming areas in the world, and the present mountains are only the latest ones. In fact, they may be considered the truncated stumps or deep seated roots of the former mountains, whose thousands of feet of overlying rock have been elevated and eroded away, so that now the basal roots are exposed at the surface. Even in Precambrian time mountains were here formed and worn down; this was repeated in the Cambrian, and in the Ordovician (Taconic), and again with the Appalachian revolution. Most of these last formed mountains were reduced during the formation of the Cretaceous peneplain, but resistant remnants or monadnocks were preserved (as Marcy), which were later again strongly uplifted (Tertiary) and now form, in the main, the present plateau at 2,000 feet and the higher mountains. The remnants of the Cretaceous peneplain now stand at an elevation of about 2,000 feet, and the Tertiary peneplain, developed below that level. Faulting took place on a large scale, previous to the ice age, and explains many of the southeastward and northwestward facing cliffs. During the ice age there was a depression of the region, overriding by the ice, with scouring and filling by glacial ice and waters, and last of all a slight elevation, with increased erosion.

It may seem strange that down through the ages influences have been at work, many of which, even today, control the life of the plants and animals now living upon the mountain. Thus the ancient igneous rock (anorthosite), has by its resistance retarded erosion and, combined with uplifts, has preserved the elevation, while softer rocks have been removed. This elevation has conditioned the alpine climate, with its many factors. The composition of this rock also, with its varied elements, and its large per cent (10.8) of lime[6] is important. The hardness of this rock is such that the minerals are made available slowly, and the high percentage of lime fails to exert the influence which would be expected. The soils now forming on the mountain from rock fragments are intermingled with the black, acid, organic material and are therefore acid.

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[6] Kemp and Reudemann. "Geology of the Elizabethtown and Port Henry Quadrangles," Bull. N. Y. State Museum, No. 138, p. 32, 1910.

Kemp[7] has called attention to the fact that, through faulting, the higher Adirondacks have a northeast and southwest trend, supplemented by minor faults at right angles to these, which break up the ranges into individual mountains, and thus form saddles or gaps which influence animals. As he expresses it (p. 201), "The little cross-passes almost always have a well-defined bear or deer trail following through." Furthermore, the drainage is affected by such topography and has a direct influence upon aquatic life. We thus see that these physical characteristics, even though of remote origin, exert today a very direct control upon existing organisms. The duration of this mountain has not only maintained Alpine biotic conditions since the ice age, but has perpetuated also a plant and animal population, which are relics of the long ago.

GENERAL ASPECTS OF PLANTS.—The Adirondack region is densely forested, the lower elevations being now characterized by deciduous hardwood forests of beech, birch and maple, with an intermixture of red spruce, balsam fir, hemlock, arbor-vitae, white pine, and few scattered deciduous species. In general, trees of all ages are represented throughout the forest, although under virgin conditions the older trees take up the larger proportion of the space. Young growth is ample in all openings, and even under the shade, owing to the shade enduring character of most of the trees (virtually all but yellow birch). Such woods occupy large areas in the Adirondacks and the Catskills. Their composition and description lie outside the scope of this paper, except where they are replaced by other types of vegetation as one goes up the mountain. The forest floor is often very beautifully covered by myriads of ferns and wild flowers such as *Cornus canadensis, Clintonia borealis, Coptis trifolia, Linnaea Americana, Oxalis Acetosella, Solidago flexicaulis* and others (fig. 4). The typical shrubs are *Viburnum alnifolium, Viburnum cassinoides, Rubus odoratus,* with, of course other species less common.

As one ascends the mountain the hardwoods gradually thin out as to size and frequency of occurrence, being replaced by the red spruce, *Picea rubens,* and balsam fir, *Abies balsamea.* From about 4,250 feet up, which may be considered the upper limit of the red spruce, the balsam fir forms pure stands except for scattering paper birch, *Betula papyrifera.*

In his "Plants of North Elba,"[8] Peck has tabulated the species and families of flowering plants and ferns as follows:

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[7] Kemp, J. F. "The physiography of the Adirondacks," Pop. Sci. Mo., Vol. 68, pp. 195–210, 1906. See also on the geology and topography of the Adirondacks, Miller, W. J., "The geological history of New York," Bull. N. Y. State Museum, No. 168, pp. 1–130, 1914; "The Adirondack Mountains," Bull. No. 193, pp. 1–97, 1917.

[8] Peck, C. H. "Plants of North Elba," pp. 1–266, Bull. N. Y. State Museum, Vol. 6, Number 28, June, 1899.

Families	71
Species	492

Modern segregation of species and the recent discovery of new kinds would probably bring the number somewhat higher, but the fact remains that the Adirondack region, judging by the only reasonably complete flora of it yet published, is characterized by a comparatively small number of species, the bulk of which are very common. Peck's flora included Mt. McIntyre, next to Marcy in altitude, but not Mt. Marcy.

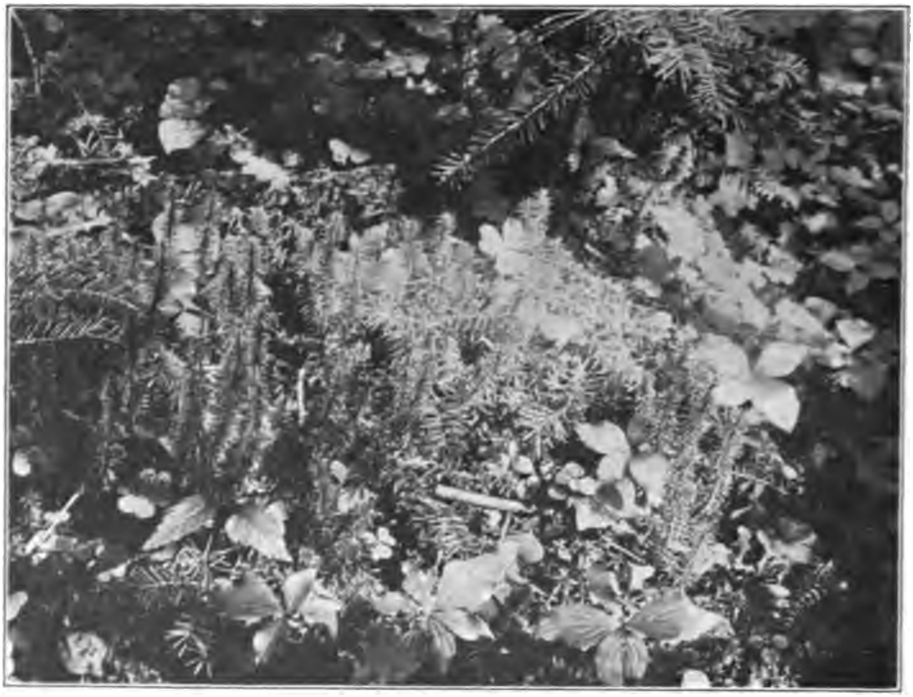

FIG. 4. Vegetation in small opening of pure fir forest at about 4,500 feet elevation, showing *Cornus canadensis, Oxalis Acetosella, Lycopodium*, and fir seedlings.

He included all introduced plants, and we have deducted these from his list, which then shows that 416 species constitute, without recent additions not yet tabulated, the actual wild flora of the mountainous part of the Adirondacks. The great bulk of these plants are of northern affinities, so that the general floristic composition of the region is fairly well indicated by the statement that the Adirondack flora is mostly northern with a limited number of species.

GENERAL ASPECTS OF ANIMALS.—In discussing the animals, in contrast with plants, allowance must be made for the fact that plants remain in evidence during stormy weather while animals tend, in general, not to be so active and attain their maximum activity during bright warm days, and then mainly during the warmest part of these days. The season (August) was also somewhat late for some species. Instrumental work and photographs further limited time for collecting. The relative scarcity of all kinds of animals was among the main features observed. This applied to both the invertebrates and the vertebrates. The scarcity of birds and mammals was conspicuous about our camp in the saddle at 4,355 feet, and these conditions seemed to hold up to the timber line. At camp there was a clearing due to the prolonged use of the site for that purpose. At Lake Tear a collection was made to get representative animals of an *open space,* and for comparison with the open mountain area above the timber line.

Above timber line the poverty of the fauna was very striking, and especially in the small number of animals that can be considered alipne. This is particularly noteworthy in connection with the animals mentioned by Colvin[9] (pp. 363–374) some of which have apparently since disappeared, as also have a number of plants mentioned by Peck as discussed below. The disappearance of the animals is, however, less certain than that of the plants because Colvin's notes were made largely in winter when there would naturally be more alpine animals which had come south. In general the collections suggested that the animals taken were an overflow from the richer lower level. We must look upon the peak of Marcy, with its relatively small area in a sea of forest, as a mere island of open. As a habitat the total area in the Adirondacks above timber line would equal only a small Adirondack lake. This open area in a forest region is somewhat (although inverted) similar to an open swamp or forest glade, and for this reason it is rather natural to expect in such conditions those animals which frequent the forest glades on warm days. The seasonal migration of animals up the mountain, as the season advances, favors just such concentration in the upper open places.

CLIMATE.—Colvin states that, if snow be the criterion, the summit of Mount Marcy enjoys barely two months of summer. Snow often whitens the mountain at the beginning of July, and a temporary covering comes in the first part of September. The climatic winter of the summit commences in the latter part of September or first of October, and ends in June.

No weather station records have been kept on Mt. Marcy and in trying to get some idea of the weather to which the mountain is subjected, the records from the stations nearest to it have been studied. These stations, with their airline distances from the summit of Marcy, and the elevation of them are as follows:

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[9] Colvin, V. "Seventh annual report of the topographical survey of the Adirondack region of New York, to the year 1879." Albany, 1880.

Gabriels	13 miles N.W.	1,729 feet
Lake Placid	7 miles N.	1,864 feet
Keene Valley	4½ miles N.E.	1,012 feet
North Creek	35 miles S.S.W.	1,002 feet
Indian Lake	37 miles S.W.	1,660 feet

Records from stations below 1,000 feet have not been used. A comparison of the records from these five stations, which have been kept over a period of years, shows a good deal of difference in the climate on the north and south-facing slopes of Marcy. Averaging the annual mean temperature shows 42.13° F. for the stations south of the mountain, and 39.54° for those north of it.

The minimum temperature for the stations north of the mountain, averaged over a period of years, is —36°, for the stations south of the mountain —28.4°. The snowfall for stations north of Marcy averages 127 inches (unmelted), while for those to the south it averages 78 inches a year. The maximum temperatures are much more uniform, averaging for the northern stations 92°, and for the southern ones 95°. No continuous records have been kept at the summit of Marcy, but Colvin mentions that a recording thermometer left there by him over the winter of 1875 registered —23°, but it was probably snow covered and "shows the minimum winter temperature of the rock at the summit rather than that of the air."[10]

Due to the precipitous topography, and the purely local nature of early and late frosts, the length of the growing season does not show such well-marked differences as temperature and snowfall appear to do between the north and south sides of the mountain. Taking the region of which Marcy is roughly the center, the growing season has averaged 92 days, compared with about 120 days in the Catskills, and over 200 on Long Island. The longest period has been 142 days; the shortest, 52 days. So far as the weather bureau records show, the latest frost in the spring came on July 20, the earliest on August 18, not, of course, in the same year.

These records give only a very general idea of the climatology of the Marcy region. The amount of variation from day to day, the differences between the south-facing and north-facing slopes, and the apparent waywardness of precipitation in its distribution is baffling if any general statement of the climate of the mountain is attempted. The precipitation is distributed rather uniformly over the year. Eight months have, at different times, shown the highest precipitation of the year. All months have shown the minimum at one time or another. On the whole the precipitation is high and sporadic.

The prevailing winds over a long series of years have been northeast or west, except that at Keene Valley they seem to be about evenly distributed between northwest and south.

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[10] Colvin, V. Loc. cit., page 328.

None of the figures cited give any real picture of the climate within the area of this study. The elevation is so much greater, the wind so much stronger, and the exposure near and above timber line relatively so great compared to the weather stations which are in the valleys. On June 5, 1919, near the summit of Marcy we found considerable unmelted snow. The general impression which even a brief period spent there gives, is that during the summer the precipitation is so plentiful that the forest floor just below timber line is wet a considerable part of the time. No one knows definitely how much of the time the mountain is cloud-capped; but certainly the humidity is greater than any records taken 3,500 feet below the summit would suggest. It is nevertheless possible that intervening dry periods may make moisture a limiting factor particularly in exposed situations above timber line.

III. INSTRUMENTAL DATA ON THE LOCAL ENVIRONMENT

STATIONS AND INSTRUMENTS.—Certain of the factors that are known to influence the occurrence of plants and animals[11] are capable of measurement and study from the instrumental viewpoint, but the very position of the instruments on Mt. Marcy is naturally dictated by what the vegetation at different elevations shows to be critical points in the vegetative covering of the mountain.

These critical points, at least on the south side, are:

a. Lower limit of fir forest at 4,250 ft.
b. Bog at east end of Lake Tear, at 4,320 ft.
c. 1. Dwarf fir forest just below timber line, at 4,890 ft. in tree crowns.
  2. Same as 1 but on the ground under the forest to show conditions affecting reproduction.
d. Alpine zone above timber line, 4,900 ft. to summit, station at 4,920 ft.

Stations *a* and *b* are about a mile apart and about a thousand feet below the summit. Stations *c* (1 and 2) and *d* are only 75 feet apart and with a difference of but 30 ft. in altitude.

These different types of vegetation, quite unmistakable in their definiteness, and obviously the result of various factors, each occupy large areas on the upper slopes of the mountain, except the bog at Lake Tear which is probably not over 10 acres in extent.

The number and type of instruments used was limited by the practical problem of transportation from the base to the camp near the top of the mountain. For this reason it was impossible to use recording instruments. Evaporation and solar radiation were studied with the Livingston black and white spherical atmometer bulbs. It was not practical to use the rain correcting type. Accordingly, some of the bulbs were mounted on glass tubing which extended into a wide-mouth reservoir through a glass stopper. In this stopper was a second tube of somewhat wider bore which was flush with the bottom of the stopper and extended above the stopper about 1½ inches. This was the filling tube. On it a file mark was made and the distilled water in the reservoir was brought to a level with this mark. A 50 cc. burette was used in refilling the reservoir, and, owing to the small bore of the filling tube, very accurate readings were possible. To prevent water loss through the filling tube a cork stopper with a small groove along one side was used. The other bulbs had only one tube from the bulb to the reservoir and the file mark was made in the neck of the bottle. This type is less satisfactory, because it does not permit such accurate readings.

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[11] Our knowledge of the factors of the environment, and of how they act and how organisms respond, is still very inadequate, but is being increased with gratifying rapidity. Witness Garner and Allard's notable discovery of the control exerted by the relative length of day and night upon the growth and flowering of plants. (Garner, W. W., and Allard, H. A.. "Effect of relative length of day and night and other factors of the environment on growth and reproduction in plants." Jour. Agr. Res., Vol. 28, pp. 553–605, March, 1920.)

The water loss from the black atmometer was taken as an indication of the solar radiation because it is more influenced by light intensity than the other, and takes into consideration this additional factor, thus giving a more complete record of the complex combination of physical factors which make up a habitat.[12] The solar radiation was determined by subtracting the water loss of the white atmometer from that of the black, expressing the difference in cubic centimeters. Air temperatures were taken with the Weather Bureau type of maximum and minimum thermometers shaded from the sun. The soil temperatures were taken with a soil thermometer.

Station a.—This station was on a steep rocky mountain side facing northeast, at the lower limit of the fir forest where there is still an occasional large spruce representing the upper altitudinal limit of this tree. The reproduction was nearly pure fir (a more complete description of this forest will be found under IV, Plants and Animals). Below this station the spruce increases in proportion, while a short distance higher up it drops out completely. The atmometers were attached to the cut-off tops of fir saplings at a height of 8 to 9 feet above the ground in order to represent the crown conditions of young trees in openings of the forest. The surrounding trees were much higher, ranging up to 45 feet; but owing to the slope of the ground the instruments were fully exposed on the side away from the mountain except for about one hour each day. The topography allowed the sun to strike this slope for about two thirds to three quarters of the period it was above the horizon at this time of year. The thermometers were placed on a tree at 6 feet above the ground under a suitable shelter of boards.

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[12] The importance of solar radiation in controlling transpiration is shown in Briggs and Shantz "Hourly transpiration rate on clear days as determined by cyclic environmental factors." Jour. Agr. Res., Vol. 5, 584–649, 1916, in which they state (p. 647) that "radiation may be looked upon as the primary causative factor in the cyclic changes."

Station b. Lake Tear bog in which this station was located occupies an open area which is nothing more than a widened part of the depression between Mt. Marcy and Mt. Skylight, sheltered on all sides by the surrounding forest and on the northwest and southeast by the mountain slopes as well (See fig. 5). The vegetation consists of bog plants, several alpines, and a few isolated fir trees. The atmometers were placed in the open with their reservoirs buried in the dense mat of sphagnum, the bulbs about 5 inches above the surface of the moss. The thermometers were fastened to an adjacent fir tree at about the same level as that of the atmometer bulbs.

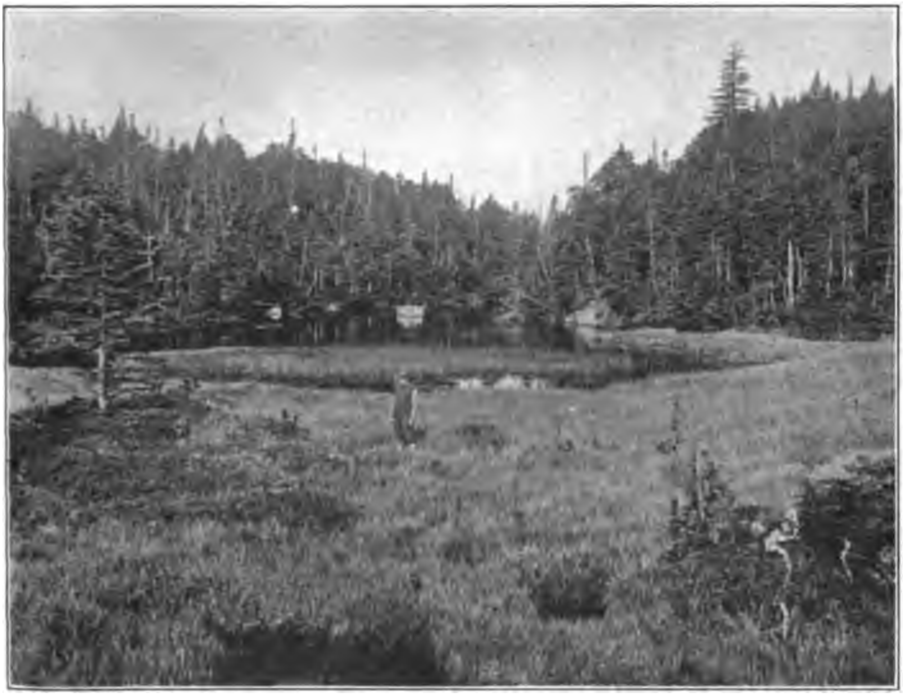

FIG. 5. Lake Tear and the bog, headwaters of the Hudson River, 4,320 feet elevation. Atmometers of station *b* are visible in front of the standing figure.

Stations c 1 and c 2.—These stations were on a shoulder of the mountain in the extreme upper edge of the continuous forest where it reaches timber line. They were in an even stand of fir trees, 7 to 12 feet high, with a maximum breast height diameter of 6 inches, and average of about 3 inches. The tops showed wind damage on the northwest. It seemed best to take records both near the tops of the trees and also under their rather dense crowns. This would give data concerning the conditions under which the

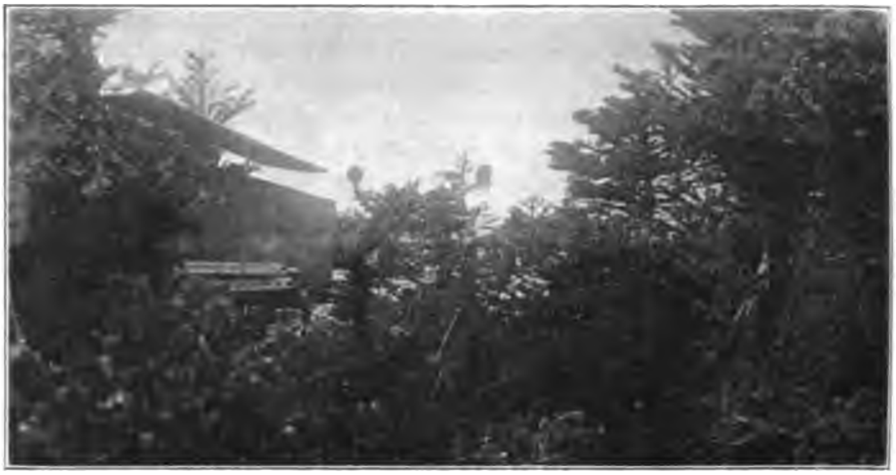

FIG. 6. Station *C*1, showing instruments set in the tops of trees to measure the environment of the forest canopy.

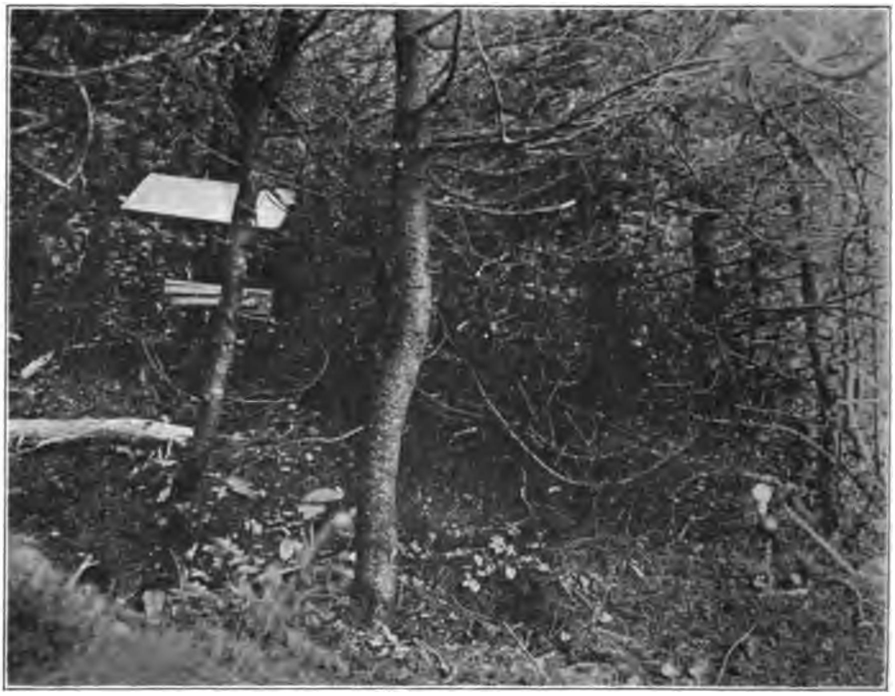

FIG. 7. Station *C*2, showing instruments set under the dense cover of the dwarf fir to measure the environment of the forest floor.

present trees live and an idea of some of the factors influencing natural reproduction. Hence station *c* 1 (fig. 6) and station *c* 2 (fig. 7) were established. In placing the instruments at the former, the tops of trees were removed and the instruments so placed that they were as fully exposed as the tops of the trees had been. The atmometers, especially the white one, could be seen from long distances. The thermometers were located on adjacent trees with similar exposure, care being taken to protect them, however, from the direct rays of the sun. At station *c* 2 the atmometers were placed about 5 inches from the ground, their reservoirs being buried in the heavy covering of moss; the thermometers were attached to trees at about 2 feet above the forest floor. This station was protected from wind, the light was very weak, and the atmosphere was at all times during the study apparently near saturation.

Station d.—This station was located at the lower edge of the alpine vegetation just above the continuous forest. It was on a rock ledge which sloped steeply down to stations *c* 1 and *c* 2, and in one place formed a cliff of about ten feet high. The cliff coincided with timber line. At the station was a layer of peat about four inches thick covered with a dense mat of low shrubs. The atmometers were placed in a north and south line fully exposed. A few yards to the north at the same elevation was a depression in which a few

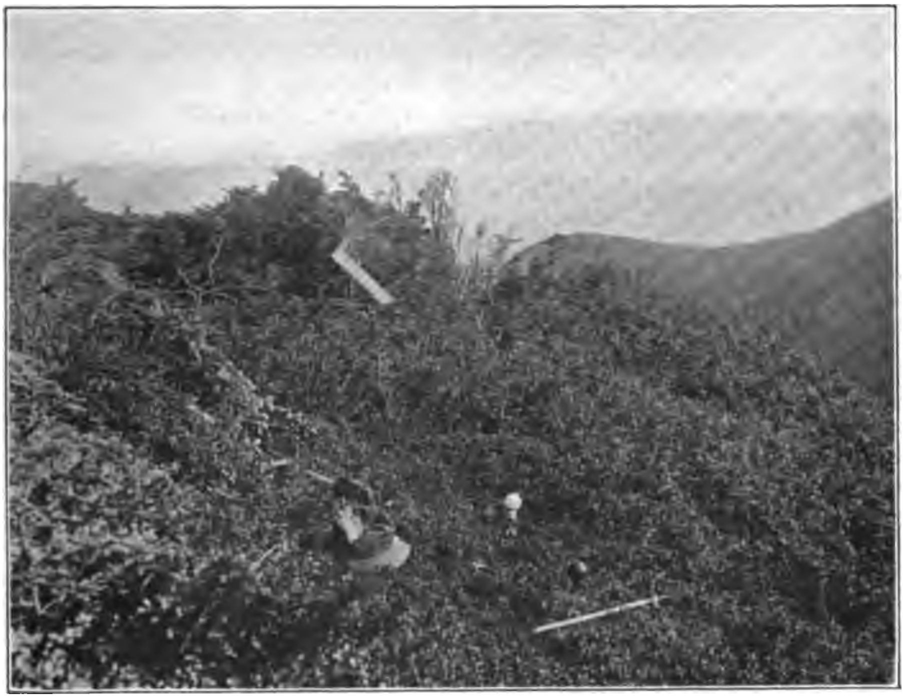

FIG. 8. Station *d* just above timber line, showing atmometers and thermometers.

stunted fir trees reached a height of about 8 feet, their tops extending only a few feet above the general level of the ground. The thermometers, properly protected from the sun, were fastened to one of these trees at about the same elevation as the atmometers (fig. 8).

EVAPORATION AND SOLAR RADIATION.—It was not possible to make readings at such widely distributed stations at 6 A.M. and 6 P.M. as would have been desirable. The readings were taken for the most part between 8 and 9 A.M. and 5 and 6 P.M. They divide the 24 hours roughly into two parts, 10 and 14 hours long respectively, and the graph marked "day" shows the conditions for the shorter period. In the case of the atmometers it was deemed best to add the morning reading to the night reading. This was done because on sunny days the light struck the atmometer a long time before the reading could be made. Very little water evaporated from the bulbs during the night and in fact on rainy nights the reservoir filled so that it was necessary to make the readings from the bottom of the cork stopper instead of from the file mark.

During the first three days of the field study heavy clouds hovered over the mountain tops, and a large part of the time it was raining. The fourth day the sky cleared considerably and the sun appeared. The remaining days were comparatively bright. During the entire period of observation there was a strong wind which was felt especially at the upper stations. The weather conditions did not in all probability differ much from those on Mt. Mansfield in Vermont (elevation 4,075 ft.), where recording instruments were stationed. These instruments show that on the fourth day mentioned above there were only 71 minutes of sunshine, on the succeeding days there were 567, 500, 580, and 60 minutes respectively. The wind movement for these days was 256, 330, 587, 520, and 665 miles respectively. During the night the humidity instrument showed that the air was saturated while during the day the humidity was never lower than 50 percent. These data are shown in figure 9.

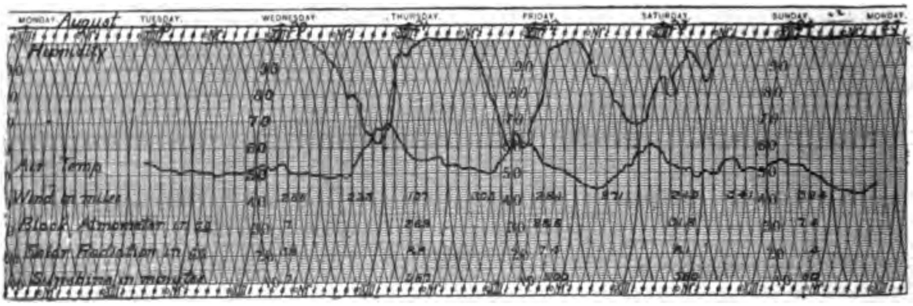

FIG. 9. Weather conditions on Mt. Mansfield, Vermont, August 19 to 25, 1919.

TABLE 1. *Evaporation and solar radiation data collected on Mt. Marcy*
Corrected readings of the atmometers and solar radiation expressed in cc.

	Date				
	Aug. 20	Aug. 21	Aug. 22	Aug. 23	Aug. 24
Station *a*:					
Black Atmometer	2.3	16.5	13.5	19.	1.8
White Atmometer	1.5	8.4	6.1	10.3	.7
Solar radiation	.8	8.1	7.4	8.7	1.1
Station *b*:					
Black Atmometer	11.1	20.7	20.6	29.4	5.4
White Atmometer	4.	7.6	9.3	14.6	1.7
Solar radiation	7.1	13.1	11.3	14.8	3.7
Station *c* 1:					
Black Atmometer	9.1	20.	16.4	27.3	4.9
White Atmometer	3.3	7.4	7.	13.3	2.
Solar radiation	5.8	12.6	9.4	14.	2.9
Station *c* 2:					
Black Atmometer	0.	3.7	2.1	5.8	3.5
White Atmometer	.5	3.2	1.5	5.4	3.
Solar radiation	0.	.5	.6	.4	.5
Station *d*:					
Black Atmometer	12.9	24.	20.7	36.2	6.6
White Atmometer	5.6	9.7	12.	20.	2.6
Solar radiation	7.3	14.3	8.7	16.2	4.

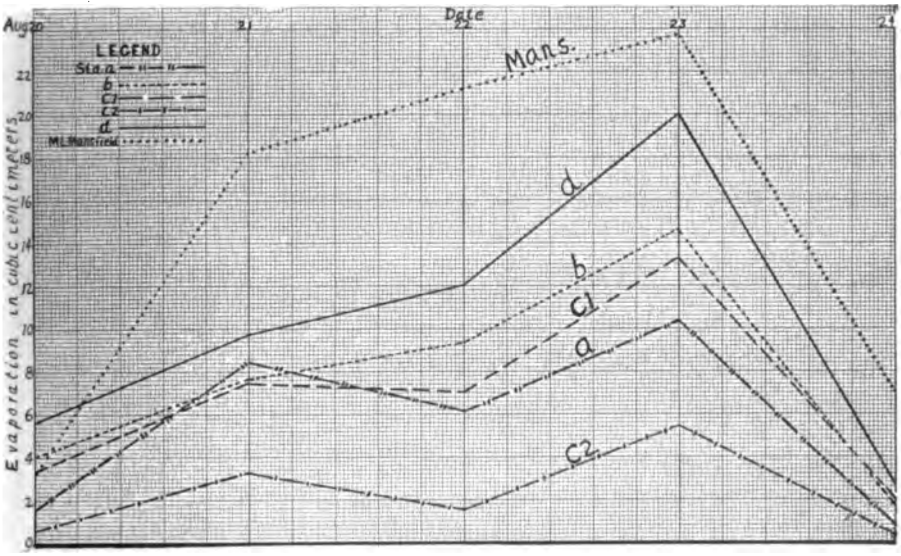

FIG. 10. Evaporation from white spherical atmometers at each station on Mt. Marcy from August 20 to 24, 1919. Evaporation at the summit of Mt. Mansfield, Vermont, is included for comparison.

The corrected readings of the two types of atmometers are given in table 1, and are shown graphically in figures 10, 11 and 12. Figure 10 shows the evaporation from the white atmometers. The highest evaporation occurs above timber line at station *d*, and, except for station *c* 2 which was under the dense fir, and station *c* 1 which will be discussed below, the rate of evaporation shows a tendency to increase with elevation (see also fig. 11).

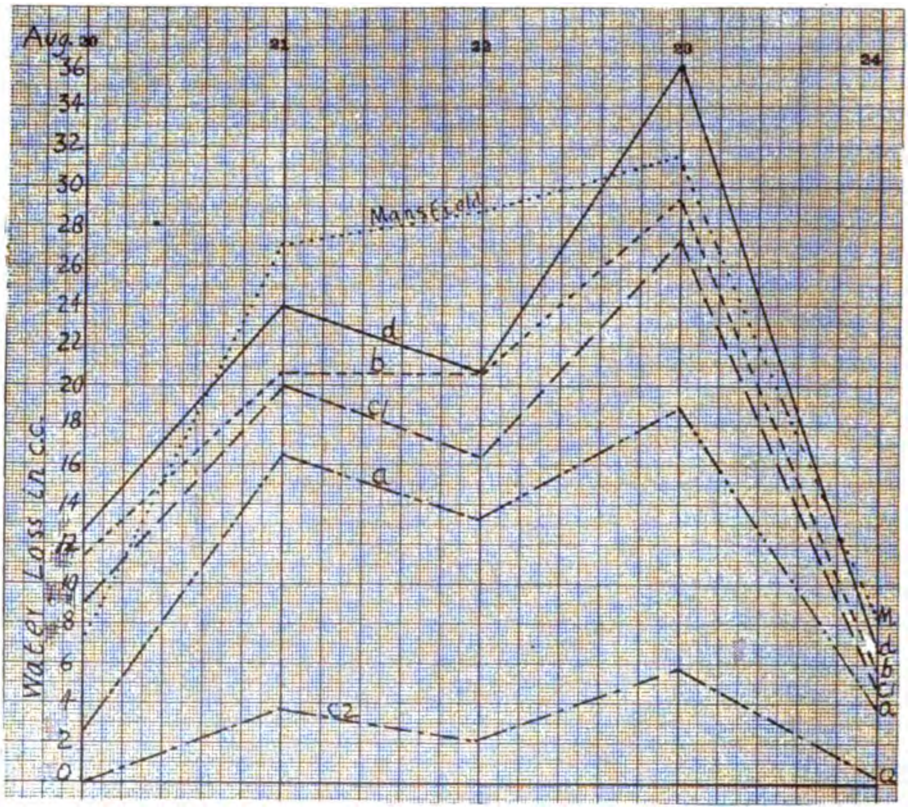

FIG. 11. Water loss from black spherical atmometers at each station on Mt. Marcy, and at the summit of Mt. Mansfield.

The rate in the bog (station *b*) is higher than the rate on the mountain side just below timber line (station *c* 1) in spite of the greater exposure to sun and wind movement at the latter point. This cannot be due to greater cloudiness at station *c* 1, because station *d*, only 75 feet away, showed an even higher evaporation than the bog. It can hardly be due to interception of the wind by the surrounding tree tops because the atmometers were placed above the shelter of these. The question presents itself as to whether or not the stream of moisture transpired by the trees and drawn upward from the forest floor, which at this time was very wet, can be the cause of the lower evaporating rate just below timber line as compared with that just above and in the bog. The moisture transpired by the trees is in all probability greater than that transpired by the much thinner layer of comparatively xerophytic bog plants; that coming through the forest from below, is also probably greater than that which comes from the sphagnum of the bog. It is therefore not unlikely that the volume of moisture coming up from the forest is enough greater than that rising from the bog to produce the difference in evaporation shown by the instruments.

Figure 11 represents graphically the water loss from the black atmometers. Here again the highest rate occurs just above timber line. The stations arrange themselves in the same order as for the white atmometers except that the rate at the lowest station (*a*) is lower than that at the bog (*b*) throughout.

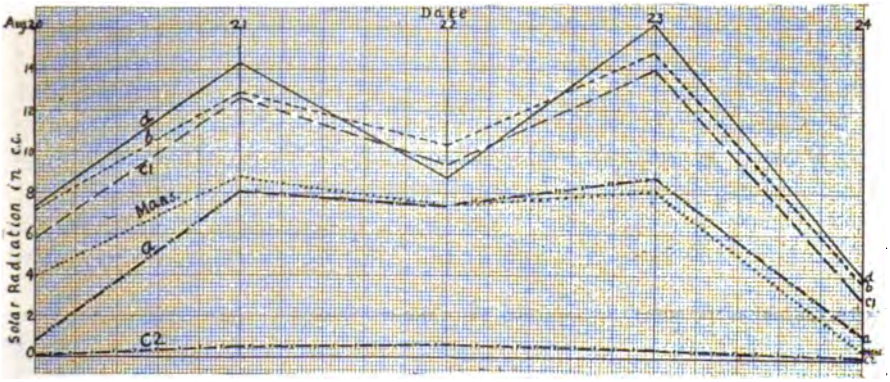

Fig. 12. Solar radiation expressed in cubic centimeters, at each station on Mt. Marcy and at the summit of Mt. Mansfield.

A comparison of the graph representing the rate of evaporation from the top of Mt. Mansfield shows a marked similarity with Mt. Marcy except on August twenty-second when it does not have the dip shown on Marcy.

Figure 12 shows graphically the amount of solar radiation as expressed by the difference between the water loss from the white and black atmometers given in number of cubic centimeters. Solar radiation above timber line was the greatest. If this be taken as 100 percent then the stations arrange themselves as follows: Station *d,* 100 percent; Station *b,* 99 percent; station *c* 1, 89 percent; station on Mt. Mansfield, 56 percent; station *a,* 51 percent, station *c* 2, 4 percent.

It was observed that at times the sun rays pierced the crowns of the fir trees above *c* 2, and struck the bulbs for a few minutes. This probably accounts for the small amount of solar radiation there. In a similar station on Mt. Mansfield during this same period no solar radiation was recorded. Although the fir seedlings have excellent moisture conditions for establishment, as indicated by the low evaporation at station *c* 2, the sunlight which penetrates the dense canopy is insufficient for their development; only when the cover is opened by the death of an old tree can the young trees come up.

The three chief factors which enter into the consideration of the variations recorded above are elevation, clouds and exposure. Station *c* 2, as has been said, was never long subjected to the direct rays of the sun. Station *a* was shaded during part of the day by Mt. Skylight and the vegetation on the mountain side. Local clouds were abundant. At times *d* and *c* 1 were in the clouds while *b* was in the bright sunlight. At other times a heavy mist would cover the atmometers at *b* while the upper stations were in the sunshine.

It is interesting to note that while the water-losses from both the white and black atmometers on Mt. Mansfield at an elevation of 4,075 feet were larger than from any station on Mt. Marcy, the solar radiation was only 56 percent of that above timber line on Marcy.

Temperature.—The temperature readings are given in table 2, and shown graphically in figures 13 and 14. The variations from day to day were not great at any of the stations, the maxima varying a little more than the minima. The differences in maximum and in minimum temperature between the stations were small.

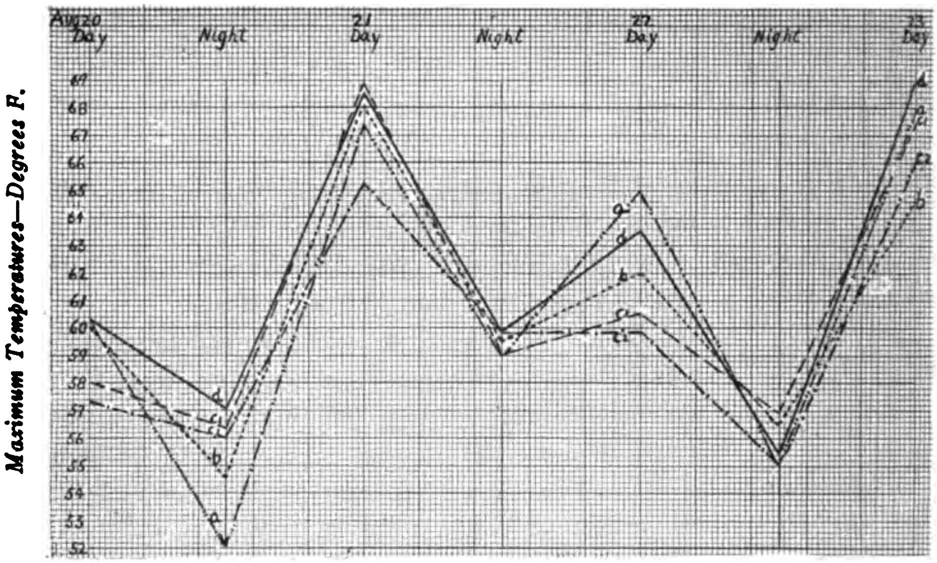

Fig. 13. Maximum temperatures at each station on Mt. Marcy.

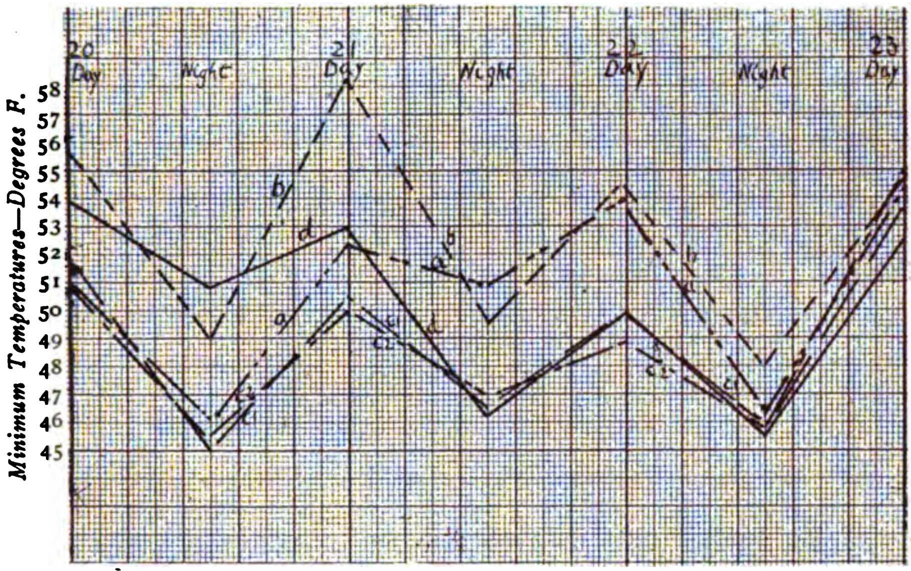

FIG. 14. Minimum temperatures at each station on Mt. Marcy.

TABLE 2. *Temperature readings on Mt. Marcy, August, 1919*

Station	20	21		22		23		24
	Day	Night	Day	Night	Day	Night	Day	Day*
a. Max.	60.3	52.	67.4	59.	65.	55.	67.8	60.9
Min.	51.	46.	52.3	50.9	54.	46.2	54.5	50.
Ave.	55.6	49.	59.9	55.	59.5	50.6	61.7	55.5
b. Max.	60.	54.5	68.	59.5	62.	56.5	64.5	59.7
Min.	55.5	49.	58.2	49.5	54.5	48.	54.8	55.8
Ave.	57.8	51.8	63.1	54.5	58.3	52.3	59.7	57.8
c – 1. Max.	58.	56.3	68.8	59.	60.5	56.9	67.6	58.9
Min.	51.8	45.	50.4	46.5	49.9	45.4	53.5	49.8
Ave.	54.9	50.7	59.6	52.8	55.2	51.1	60.6	54.4
c – 2. Max.	57.3	56.	65.3	59.8	59.9	55.	66.1	58.8
Min.	51.	45.4	50.	46.9	48.8	45.7	51.	49.5
Ave.	54.2	50.7	57.7	53.4	54.4	50.1	58.6	54.2
d. Max.	60.3	57.	68.5	59.8	63.5	55.3	68.9	58.7
Min.	53.8	50.8	53.	46.3	49.8	45.5	52.4	46.9
Ave.	57.	53.9	60.8	53.	56.7	50.4	60.7	52.8

* No night readings for August 23–24.

Bonnier[13] states (p. 336) that the modifications of structure in alpine plants are related to the diurnal range of temperature, which is very low at night and relatively high in the sun during the daytime. Although our thermometers were sheltered from the direct rays of the sun (which gives a smaller range), our results agree in the main with the set of conditions found by Bonnier. The average range of temperature (difference between maximum and minimum) increased with altitude except that the station just below timber line (*c* 1) had a little greater range than just above timber line (*d*). The average ranges, in order of magnitude, are as follows:

Station *c* 1	11.7	degrees F.
Station *c* 2	11.3	" "
Station *d*	10.5	" "
Station *b*	7.4	" "
Station *a*	7.1	" "

Sampson[14] has shown, as a result of studies in the plant zones of the Wasatch Mountains in Utah, that the summation of effective temperatures as proposed by Merriam[15] gives results similar to temperature summations on the physiological basis as devised by Lehenbauer.[16] These summations "have shown much promise in correlating air temperature with physiological plant activities." Summations of our temperature data according to Merriam's method (totals of the mean daily temperature, less 40 degrees) show that the heat available for growth diminishes with increasing altitude, except for the bog at Lake Tear which had the highest effective temperature, due undoubtedly to its longer exposure to the sun as compared with station *a*. Taking the effective temperatures at station *a* as 100 percent, the other stations were as follows:

Station *a*	100	per cent.
Station *b*	105	" "
Station *c* 1	95	" "
Station *c* 2	89	" "
Station *d*	76	" "

It is significant that the greatest change in amount of effective temperatures should occur between the points just below and just above the timber line, in spite of the short distance (hardly 75 feet) between these two points, and that this change should correspond with the abrupt contact between the two life zones. Does not this suggest that the amount of effective temperature may be the leading factor which causes the sharp line of demarkation at timber line?

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[13] Bonnier, Gaston, "Le Monde vegetal" E. Flammarion, Paris, 1914.

[14] Sampson, A. W. "Climate and plant growth in certain vegetative associations," U. S. Dept. Agr. Bul. 700: 1–72. 1918.

[15] Merriam, C. Hart. "Laws of temperature control of the geographic distribution of terrestrial animals and plants," Nat. Geog. Mag., Vol. 6, pp. 229–238, 1894.

[16] Lehenbauer, P. A. "Growth of maize seedlings in relation to temperature," Physiological Researches, Vol. 1, No. 5, pp. 247–288, 1914.

SOIL TEMPERATURE.—The soil at all stations was essentially a bog soil. Analysis shows that its water content varied from 76 percent to 85 percent, of its original weight. As is well known, soils of this nature do not fluctuate much in temperature on account of the great mass of water to be warmed. The readings obtained were:

TABLE 3. *Soil temperature.*

Depth	Stations			
	a	*b*	*c1* and *c2*	*d*
1½ in.	54	58.5	53	55
3 "	52.5	53.5	49.3	50
8 "	—	—	—	47.5
12 "	50	49.5	46.3	—

Temperature in adjacent sandy soils at a depth of one inch were about 20 degrees warmer during the afternoon on sunny days and fluctuated as much as 13 degrees during 24 hours. On one day the maximum soil temperature at this depth was 76 degrees, the minimum, 63°.

SOILS.—Samples of the surface soil were taken in each of the important types of vegetation represented by the stations described above. Since the feeding roots of most plants are close to the surface these samples are fairly representative, although final conclusions would require a larger number, including some of the deeper layers. The mineral soil over most of Mount

TABLE 4. *Soil samples from Mt. Marcy.*

Station	Water, percent	Dry matter, percent	Dry matter contains organic and volatile sub., percent	Ash, percent	Organic and volatile contain nitrogen, percent	Relative lime absorption coefficient	Depth of sample
b	84.79	15.21	12.24	2.97	.312	1	8 in.
b	82.64	17.36	13.40	3.96	.304	1.2	1 ft.
d	76.07	23.93	21.93	2.00	.500	2.2	8 in.
c	80.31	19.69	18.89	.80	.455	2.3	1 ft.
a	81.36	18.64	17.62	1.02	.388	2.1	1 ft.
d	50.75	49.25	17.78	31.46	.389	1.5	8 in.

	100 parts dry matter contain			
	Organic and volatile	Ash	Nitrogen in organic matter	Depth of sample
b	80.47	19.53	2.05	8 in.
b	77.20	22.80	1.75	1 ft.
d	91.63	8.37	2.09	8 in.
c	95.05	4.05	2.31	1 ft.
a	94.53	5.47	2.08	1 ft.
d	36.10	63.90	.79	8 in.

Quality of organic and volatile matter as regards nitrogen is nearly similar. All samples show a large lime absorption coefficient, indicating high acidity.

Marcy is derived from a coarsely crystalline, greenish anorthosite containing approximately ten percent of lime. This rock, even when pounded to powder, gave a hardly perceptible effervesence with hydrochloric acid, but when heated it effervesced strongly.

The analyses of the samples are given in table 4. None except sample 6 contained appreciable quantities of the mineral soil. It is interesting that the mineral soil, even though derived from rock with a marked percentage of lime is nevertheless acid. The analyses indicate that the major differences in the vegetation at the instrumental stations are probably not due to differences in the soil. There are however, examples of plant responses to soil composition as in the case of *Arenaria groenlandica* and *Scirpus caespitosus* which grow on the particles of the rock that do not yet contain sufficient organic matter to become strongly acid. Such a case is noted below under the description of the vegetation of the alpine zone.

The above data probably do not cover a critical period in the conditions of the habitats which were under consideration. At no time were the plants subjected to extreme conditions in light intensity, air or soil temperatures, humidity or soil moisture. Only data collected at such critical periods, that is when one or more of the environmental factors was reduced to its minimum for that habitat, could be used to determine its effect upon plant distribution. That periods exist when conditions are less favorable than they were during our stay was plainly recorded by the vegetation. Although not covering a critical period, the instrumental data indicate certain important differences in the habitats studied, and the authors believe that the collection of this kind of data is valuable in pointing the way to the solution of many problems in plant distribution.

(To be continued)

Part II will contain Section IV, the detailed descriptions of the plants and animals on the various habitats mentioned above, and their ecological significance.

Part III will contain the remainder of the paper, including a map and discussion of tree distribution in relation to wind, data on the rate of tree growth above and below timber line, and an analysis of the vegetation in accordance with Raunkiaer's growth forms.

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PLANTS AND ANIMALS OF MOUNT MARCY, NEW YORK, PART II

Charles C. Adams, George P. Burns, T. L. Hankinson, Barrington Moore, and Norman Taylor

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IV. Plants and Animals

Part I of this paper, published in Vol. 1, No. 2, of Ecology, contained a general account of the topography, geology and climate of Mount Marcy, the general features of the plants and animals, and the instrumental data on the local environment of the habitats studied, but the details and ecological relationship of each was left for Part II.

There are certain definite types of vegetation, corresponding with definite habitats, in which the instrumental stations were placed. A description of what plants and animals live in these habitats is here presented, not only as a record and to be correlated with our instrumental data, but to trace as far as possible the history of the mountain biota and intermingling of species.

The Fir Forest.—The forest is practically continuous except for two openings of much ecological significance, the bog at Lake Tear, which is a depression, and the alpine summit, an elevation.

The belt of forest considered in this study is that growing between 4,250 and 4,900 feet in elevation, its lower limit distinguished by the disappearance of red spruce, *Picea rubens,* and its upper limit by timber line. It may be considered as a single vegetative unit composed of almost pure fir, *Abies balsamea,* with only a small admixture of paper birch, *Betula papyrifera,* but there is a marked difference in the height and diameter of the trees. At 4,250 feet the average mature firs approximate 40 to 45 feet by 8 to 10 inches in diameter at breast height; at timber line they do not exceed 7 to 12 feet in height by 5 inches (average about 3) in diameter. The change is not uniform, and stunting not very noticeable below elevations of about 4,500 feet. The stand is more nearly even-aged than would be expected with fir, and is on the whole mature. Younger trees are, however, found throughout. Reproduction is abundant in all the openings.

The value of this forest is for watershed protection, and scientific and scenic interest. Although trees large enough to be merchantable occur up to about 4,500 to 4,600 feet, the steepness and roughness of the slopes would make exploitation difficult and probably unprofitable.

Lower Limit of Fir Forest.—The point selected for this station is about half way from the place marked *Camp* (it is only a camping site) on the topographic sheet, on the trail from Upper Ausable Lake to the summit of Marcy, and the intersection of this trail with one leading to Mt. Skylight. At this place the grade is steep and the woods dense, so dense in fact that off the trail one has to cut one's way.

The forest at this point, which appears to be typical of thousands of acres with similar conditions, is composed of about 85 percent *Abies balsamea,* 10 percent *Betula papyrifera,* and 5 percent *Picea rubens.* Practically no deciduous shrubs are found as undergrowth, which is characterized by many young plants of the fir, a few of the birch, and a very small proportion of the spruce. Nearly all the trees at this point average approximately 40–45 feet high.

Under the dense shade of such woods the forest floor, nearly shrubless except in clearings, is a deep carpet of mosses, save where the moss gives way to a thick mat of needles and litter. The mosses are chiefly *Sphagnum acutifolium, Hypnum Schreberi, Dicranum scoparium* and *Dicranum longifolium.* On the higher parts of this moss carpet, on rocks and on tree stumps, is *Cladonia rangiferina,* a lichen so common that it adds a gray tone to the somber woods. This is still more true as one ascends to higher elevations.

The absence of tree reproduction as well as of herbs and shrubs under the dense coniferous canopy has been commonly attributed to lack of light. Unquestionably light is important, but is not the only factor, for the soil moisture is considerably less under a thick canopy than in small openings. This lower moisture content has been found, in some cases at least, to be even more important than lack of light.[17]

Upon the forest floor of mosses and lichens the dominant herb is *Cornus canadensis,* its scarlet berries very abundant on August 22. Next to it in frequency is easily *Solidago macrophylla,* in full flower at this time. These two plants often make up the almost exclusive growth in the shade of the trees, but scattered through them are other species, notably *Oxalis Acetosella,* which is often locally dominant.

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[17] Moore, Barrington, "Reproduction in the Coniferous Forests of Northern New England," Bot. Gaz., Vol. 64, No. 2, pp. 149–158, 1917 (see especially p. 156). Burns found in Northern Michigan that openings which were filled with young sugar maple (*Acer saccharum*) had more soil moisture as well as more light and more heat. He further found, in unpublished experiments made in a forest nursery in Vermont, that an abundant moisture supply counterbalanced the shade produced by six thicknesses of cheese-cloth. R. E. Horton (Mon. Weath. Rev. 47: 603–623, 1919, Science, 51: 439, 1920) found the interception of precipitation by trees to be "about 25 percent as an average constant rate for most trees in heavy rains of long duration." The average of 11 trees in the summer of 1918 was 40 percent.

Other plants in this forest, arranged in the order of their frequency are

Linnæa americana
Chiogenes hispidula
Coptis trifolia
Monotropa uniflora
Clintonia borealis
Carex intumescens
Vaccinium augustifolium
Viola (sp. no flowers or fruit)
Cinna latifolia
Aralia nudicaulis
Lycopodium annotinum
Rubus strigosus (in more open places)
Ribes glandulosum
Streptopus roseus
Dryopteris dilatata
Osmunda Claytoniana

In quite open places are occasional shrubs of *Amelanchier spicata,* about 3–4 feet high, but these are scarcely known from the deeper part of the woods.

While the upper limit of red spruce is the deciding characteristic of this area, the fact remains that there is here a curious welding of floral elements from above and below. No true alpine plants have come down from the top to this region, for there is scarcely one of the plants listed which could not be found in the upper level of the Catskills. Yet the shade, the very existence of the habitat which these woodland plants demand is provided by the fir which here makes up 85 percent of the forest. Down the mountain a little further this fir meets stronger competition of the red spruce, which becomes dominant still lower down. So far as the forest is concerned, the red spruce practically gives way at 4,250 feet to the fir. It is a good illustration of the herbs of moderate elevations (for the Adirondacks) running well ahead of their natural shade, the red spruce, through the mingling of spruce and fir, and up through the fir to the very edge of the timber line. Yet not one true alpine plant has penetrated down through the fir forest to this level.

The fir, which is found in protected places, almost to the summit of Marcy, hundreds of feet above timber line, successfully meets the competion of lower-elevation trees, showing an adaptability to diverse conditions immeasurably greater than its herbaceous associates on the summit which are unknown in these woods.

Conversely most of the plants associated with this upper limit of the spruce, denizens on the whole of lower elevations, seem perfectly at home at this level. Their frequency of occurrence is different at different elevations above this, but not many of those listed fail to reach the topmost limits of the forest. More will be said of this in the discussion of the forest-floor vegetation just below timber line, and of the vegetation above that point.

VERTEBRATES OF THE FIR FOREST.—For comparison with the fir forest of the higher altitudes the following brief summary of recorded observations on the mixed hardwood area are of special interest.

While passing along the stream bed between the Upper and the Lower Ausable Lakes, two Deer, *Odocoileus americanus borealis* Miller, were seen; one was a fawn about half-grown. It is likely that many species of birds are present in the lower forest. Eaton[18] (pp. 42–50) describes the bird life of the Marcy region as he noted it in the early part of the summer of 1905, and found over a hundred species of birds nesting within ten miles of the mountain (p. 50). Since, although the forest cover is continuous, less than 30 species of birds nest above the hardwood zone (2,500 feet), it is very probable that most of these species are practically confined to the mountain base and that this is the chief bird habitat of Mount Marcy.

Miller[19] records over thirty species of mammals from Essex County, New York, and most of these from the lowland areas, principally from Elizabethtown. Very probably most of these species live on Mount Marcy. Other birds were noted here, but these were not clearly enough seen for identification. Most of these were warblers.

Above the hardwoods in the fir forest a small flock of perhaps a dozen white-winged crossbills, *Loxia leucoptera,* flew to some tree tops near our camp. Red-breasted nuthatches, *Sitta canadensis,* were often heard. In Eaton's account (loc. cit., pp. 42–50) the following species were found on the upper part of Mount Marcy above 4,000 feet, and undoubtedly in the growth of tall balsams and red spruces: Arctic three-toed woodpecker, *Picoides arcticus,* three-toed woodpecker, *Picoides americanus americanus,* blue jay, *Cyanocitta cristata cristata,* Canada jay, *Perisoreus canadensis canadensis,* slate-colored junco, *Junco hyemalis hyemalis,* black and white warbler, *Mniotilta varia,* myrtle warbler, *Dendroica coronata,* pine warbler, *Dendroica vigorsi,* winter wren, *Nannus hiemalis hiemalis,* red-breasted nuthatch, *Sitta canadensis,* Acadian chickadee, *Penthestes hudsonitus littoralis,* golden-crown kinglet, *Regulus saprapa saprapa,* ruby-crowned kinglet, *Regulus calendula calendula,* Bicknell's thrush, *Hylocichla aliciæ bicknelli,* olive-backed thrush, *Hylocichla ustulata swainsoni,* hermit thrush, *Hylocichla guttata pallasi,* and robin, *Planesticus migratorius migratorius.*

Of these species the following were found by Eaton breeding on Marcy between altitudes of 3,900 feet and 4,300 feet: Three-toed woodpecker, winter wren, black and white warbler, olive-backed thrush, and hermit thrush. Undoubtedly a number of other species use the tall conifer zone for nesting, where one important condition at least, namely seclusion, can be readily found. On account of the density of the cover and the extensiveness of this balsam forest, little was learned of the birds and other vertebrates of the region in our limited time. Juncoes, golden-crowned kinglets, and myrtle warblers were abundant and prominent, and the notes of some of these birds were heard at almost all times during good weather about our camp, and along the trail near it.

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[18] Eaton, E. H., "Birds of New York," Memoir 12, Part 1, New York State Musepm, pp. 1–501, 1910.

[19] Miller, G. S., "Preliminary List of New York Mammals," Bull. N. Y. State Mus., Vol. 6, No. 29, pp. 271–390, 1899. See also "Key to Land Mammals of Northeastern North America," l. c., Vol. 8, No. 38, pp. 59–160, 1900.

During the few days of field work little evidence of mammal life was noted in the region of tall balsams. Some deer tracks were seen along the trail not far from camp, and we were told by guides that the region is frequented by many deer on account of its relative inaccessibility to hunters. A little trapping was done for small mammals in the woods near camp, with wooden mouse traps, baited with bacon and corn meal. A white-footed mouse, *Peromyscus maniculatus gracilis* (LeConte), and two red-backed mice, *Evotomys gapperi gapperi* (Vigors), were taken.

There are very few published records of mammals occurring in this high coniferous forest on Marcy. Colvin[20] (p. 366) reports tracks of a panther, *Felis couguar* Kerr, near Lake Tear, and from these tracks and those of varying hares he inferred that the panther was hunting hares. He also records martens, *Martes americana americana* (Turton), in forests on the side of Mount Marcy, but says they do not occur above the timber line. He notes that they also destroy hares. Tracks in snow made by a small shrew were noted by him; these he considered to be "*Sorex personatus*," an inference which is probably correct, since Batchelder writes that the masked shrew, *Sorex personatus personatus* Geoffrey, is apparently common there and found anywhere on the mountain. Colvin also notes tracks of ermine, *Mustela noveboracensis noveboracensis* Emmons (p. 369), also fisher, *Martes pennanti pennanti* (Erxleben), and lynx, *Lynx canadensis canadensis* Kerr (p. 367). The later was near Lake Tear and also evidently hunting hares. He reports the common red squirrel (probably *Sciurus hudconicus loquax* Bangs) at 4,000 feet elevation feeding on seeds of spruce (p. 370), and he saw (p. 172) a bear, *Ursus americanus americanus* Pallas, near the headwaters of John's Brook, on the northeast side of Mount Marcy.

Mr. C. F. Batchelder in a letter writes of taking the red-backed mouse, *Evotomys gapperi gapperi* Vigors, masked shrew, *Sorex personatus personatus* Geoffrey, and rock vole, *Microtus chrotorrhinus chrotorrhinus* (Miller), in the tall conifer region on the upper part of Mount Marcy. The latter was probably taken here, but possibly in the region higher up.

A frog was heard about the grassy stream border near camp and a glimpse was had of it. Very probably it was *Rana pipiens* Gmelin. A toad, *Bufo lentiginosus americanus* (Holbrook) Cope, was taken along the trail at about 4,500 feet. No other amphibians or reptiles were seen, although special search was made, and at the time of observations weather conditions seemed favorable for these animals; but the short time of existence of these conditions (two or three months during the year) probably prevents amphibians living permanently at high altitudes on Mount Marcy. Warm-blooded vertebrates can withstand long periods of cold weather, and the dense forest cover here is undoubtedly a very favorable condition for giving them protection from enemies and from storms. There is food here for birds and mammals. Insects and seeds of conifers, and the seeds and fruits of the undergrowth are present. The following common plants here have fruits available for animals: *Abies balsamea, Cornus canandensis, Oxalis Acetosella, Unifolium canadense, Clintonia borealis, Amelanchier spicata, Potentilla tridentata* and *Trientalis americana.*

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[20] Colvin, V., "Seventh Annual Report of the Topographical Survey of the Adirondack Region of New York, to the Year 1879," Albany, 1880.

BOG AT EAST END OF LAKE TEAR, 4,320 FEET.—This lake of perhaps two acres is the chief source of the Hudson River, and the highest permanent body of water in the State (see fig. 5 in Part I). Its eastern end is bordered by a bog of about 10 acres in extent which, in heavy rains, is sometimes nearly drowned. The lake, sheltered from the wind, beautifully reflects the forest of fir which surrounds it on three sides. The steep evergreen-clothed slope of the surrounding terrain makes an admirable setting for this little mountain lake which has drawn cries of astonishment at its beauty from Colvin, Roosevelt and hosts of less renowned visitors. No aquatic flowering plants are found in the lake, the short growing season and the cold water probably preventing their establishment. On August 20 the water at 3 feet deep was 50.5° F.

The bog is not quite level and has a slow-moving, poorly draining stream flowing through it from the eastward toward the lake. This stream is irregular in its meanderings, of varying depth, and frequently is lost under the mass of bog plants that bridges over its course. Due to changes of level in the water, local irregularities of the surface, boulders that are covered by vegetation, and thus perched above the general water level, and to mounds that support trees, there are several different types of plants growing in the bog and they are associated in different ways.

In that part of the bog nearest the lake and to water level, perhaps an irregular band of 20–40 feet, the dominant plant, which makes a close mat or turf on *Sphagnum* is *Carex oligosperma,* a far northern species unknown in the Catskills, but here making dense growths. It was fruiting freely in the lower parts of the bog, only sparingly so on higher parts. Scattered through the sedge are a few plants of *Calamagrostis neglecta,* a grass not reported heretofore from New York State. It fruits very sparingly nearest the water level of the lake, but higher up in the bog numerous fruiting specimens were noted. With this grass are also scattered patches of *Carex interior,* a freely fruiting sedge found quite down to the water's edge. This turf-like growth of grasses and sedges which is often 8–12 inches high has a lower story of vegetation flat down on the *Sphagnum* and usually half hidden by the stems of the grasses and sedges. This ground-hugging element of vegetation is *Oxycoccus Oxycoccus* and *Andromeda polifolia,* never over 3–4 inches high. Very rarely are there plants of *Gentiana linearis,* elsewhere common on the upper reaches of Marcy. This lowest part of the bog is practically composed of two sedges, a grass, a cranberry and the wild rosemary. Only one of these plants, *Carex interior,* is known in any quantity from lower elevations. The other species, even if found at more moderate elevations, have all come from greater ones, and as we shall see, are common on top of Marcy, except *Andromeda polifolia.* So far as our records show, they are unknown between the level of Lake Tear and the timber line.

Perhaps three fifths of the total area of the bog, while practically level, is a few inches above that just described and contains somewhat different species of plants and quite different proportions of those common to both. Here again it is a turf-like growth but the dominant plant is *Calamagrostis neglecta* which fruits very freely. The sub-dominant plant is *Andromeda polifolia* while scattered through it and rather common, is *Gentiana linearis.* In isolated clumps are scattered plants of *Veratrum viride,* which is not infrequent. Less frequent and somewhat sporadic in their distribution are some low woody plants and a few herbs. Arranged in the order of their frequency they are:

Lonicera cærulea
Vaccinium uliginosum
Vaccinium cæspitosum
Chamædaphne calyculata
Oxycoccus Oxycoccus
Carex oligosperma (not in fruit here)
Potentilla tridentata
Houstonia cærulea
Ledum grœnlandicum
Coptis trifolia

Towards the upper or southeastern end of the bog are a few scattered trees of *Abies balsamea,* about ten in all. They are well separated from one another and from the fir forest along the edge of the bog, and are usually growing on mounds of *Sphagnum* a foot or two above the general level. Seedlings of the fir, where the general level is not too low, are common (fig. 15).

Besides these mounds which are crowned with firs, there are several without trees on them, usually scattered boulders now quite covered with vegetation which is well above the general water level of the bog. These mounds contain all the plants so far recorded from the bog, with the addition of *Chiogenes hispidula, Linnæa americana, Trientalis americana, Spiræa latifolia, Unifolium canadensis,* and *Drosera rotundifolia,* which is rare. On one such mound in the extreme northeastern corner of the bog, the rock is covered almost exclusively by *Empetrum nigrum* (fig. 15). The occurrence of this and a few other plants already noted in this bog, hundreds of feet below the bare summit of Marcy, which is in plain view, but separated by an unbroken fir forest, is interesting. It may well be that the occurrence of this crow-berry and of *Lonicera cærulea, Vaccinium cæspitosum, Vaccinium uliginosum,* and *Calamagrostis neglecta,* in this bog at 4,320 feet is the lowest elevation from which they are known in the Adirondacks. Our records from other sides of Marcy show some of them only above the timber line which is at about 4,900 feet. All except the grass were found on Mt. McIntyre at 4,800 feet, but only rarely, usually growing at greater elevations, and nowhere below the timber line. This little island of alpine and subalpine plants, evidently in a locally favorable habitat, surrounded by a dense fir forest, apparently isolated, and at a considerably lower elevation than the ecologically related plants above the timber line, was the deciding factor in choosing this bog as one of the critical points in the response of the plants and animals of Marcy to their environment.

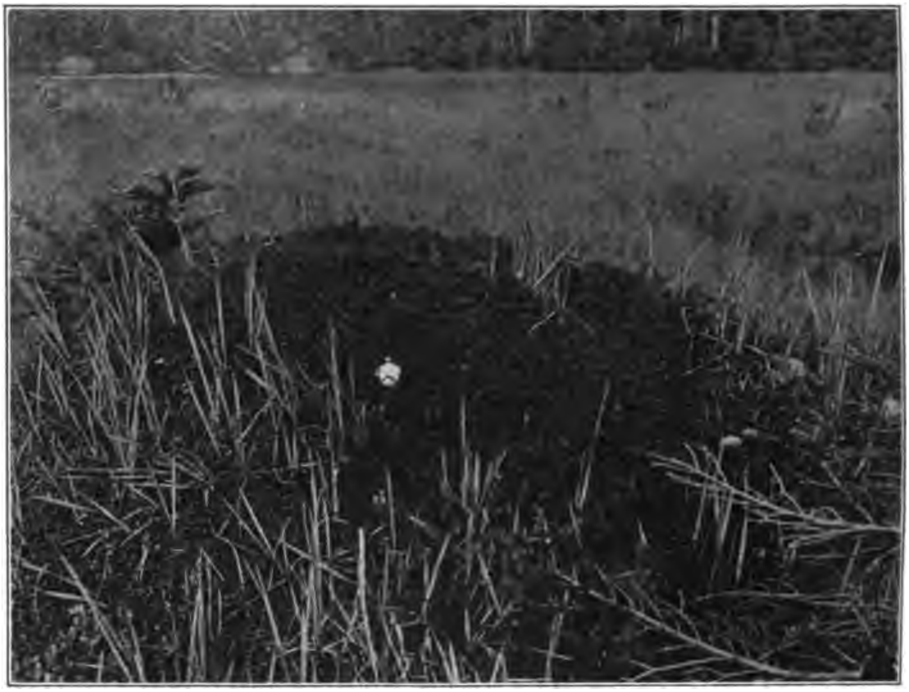

FIG. 15. Crowberry, *Empetrum nigrum,* growing on a boulder in Lake Tear bog; watch as a scale. Note also the young balsam fir.

At the extreme eastern end of the bog is a long tongue of land, slightly higher than the low end towards the lake. This is covered almost exclusively by *Calamagrostis canadensis,* which grows luxuriantly up to 3 feet tall and fruits freely. The bog is peculiar in that no *Juncaceæ* and no *Orchidaceæ* were found in it. They may occur there, but if so they are so infrequent as to make up only a minute fraction of the vegetation. That is true, also, of other plants that are not here recorded from the region.

Collections of invertebrates from the eastern side of the bog, near our thermometers (fig. 5 in Part I) gave the following: spiders, *Pardosa nigripalpis* Em. (*canadensis* Black) and *Epeira trivittata* Em., several grasshoppers, *Melanoplus atlanis* Riley, *Melanoplus femur-rubrum* DeG., *Podisma glacialis glacialis* Scudd. and *Chorthippus curtipennis* Harr., a psyllid, *Psylla strata* Patch (?), a psocid, *Psocus confraternus* Bks., and the bumble bees, *Bombus terricola* Kby. and *Bombus fervidus* Fab. There were numerous young of the grasshopper, *Chorthippus curtipennis* in the low vegetation. It is evident that the spider (*Epeira*) and insects are mainly species which live in the open, rather than in the forest. The presence of *Podisma* here, as well as in the alpine zone, is worthy of special mention on account of its similarity to the case of *Empetrum*. Colvin (loc. cit., p. 130) refers to the small aquatic bivalve molluscs, *Sphærium occidentale* Prine and *Pisidium abditum* Hald., from Lake Tear. Colvin (p. 130) also refers to seeing tadpoles of frogs in this lake.

The artificial opening at our camp, made by the many visitors to the top of Marcy, provided a small open area where a few invertebrates were taken. These were a dragon fly, *Æschna eremita* Scudd., the daddy-long-legs, *Mitopus montanus* Bks., which abounded about our lean-to, and a spider, *Steatoda borealis* Hentz. Along the Marcy trail just above camp a horntail, *Sirex cyaneus* Fab., was taken.

The few openings in the coniferous forest were especially attractive to birds, for they appeared to be more abundant at our camp clearing and at Lake Tear than in the dense forest through which the trails passed. This was very noticeable in case of juncoes and golden-crowned kinglets. Eaton (loc. cit., p. 42) notes a decided preference for slashings, clearing, burnt areas and swamps, on the part of all but fifteen species, which seem to tolerate the thick forest more than others; but even these show some preference for openings. Of these fifteen birds the following occur in the upper part of the balsam covered slopes: Olive-backed thrush, hermit thrush, red-billed nuthatch, brown creeper, *Certhia familiaris americana,* winter wren, myrtle warbler, blue jay and the Canadian ruffed grouse. Colvin (loc. cit., p. 130) mentions a "couple of snipe, which seemed to make their summer home by the shores" of Lake Tear.

DWARF FIR FOREST JUST BELOW TIMBER LINE, 4,890 FEET.—In going up the trail from Lake Tear, or on the other trails up the mountain, the fir forest becomes progressively lower as we approach timber line. The line of demarcation between unbroken forest and alpine vegetation is very sudden as there may be stunted fir trees 7–12 ft. tall at one point, and not 25 feet from them, an unbroken alpine fell-field with only much battered and isolated trees scattered through it, in locally protected places. But as defined elsewhere in this paper, the timber line is the upper limit of continuous forest, and at this point the trees are only 7–12 ft. tall. They are thick, however, relatively old, and so frequent that off the trail it is difficult to force a passage (figs. 6–7 in Part I). Almost no other tree is found associated with *Abies balsamea,* and only occasionally are there stunted paper birches, *Betula papyrifera.* The latter have all the indications of wind-swept stunting and probably it is mostly to this wind agency that their gnarled appearance is due.

There is no deciduous shrubby undergrowth of any sort in the shade of these sturdy little firs, the forest floor being made up mostly of *Sphagnum acutifolium, Hypnum Schreberi, Dicranum scoparium,* and *Dicranum longifolium,* and perhaps others. In this soft, mossy cushion, like a sponge for holding water, there are a few herbs of which the commonest, the almost exclusive one, is *Oxalis Acetosella.* Next to it in frequency is *Clintonia borealis.* Among these two herbs there are scattered a few others, which in the order of their frequency are:

Solidago macrophylla
Cornus canadensis
Linnæa americana
Chiogenes hispidula
Unifolium canadensis
Ophrys cordata (rare)

No true alpine alpine plants are found here in these shaded nooks which are quite out of the wind, so dense is canopy of the dwarf firs. Yet only a stone's throw above is the open bare summit of Marcy with the Lapland Rhododendron and the other alpine plants growing in the blazing sun, and beaten upon by the full force of the winds.

This fir forest provides shade for a handful of species of herbs from moderate elevations, but not one true alpine plant penetrates down through the barrier of timber line. All the species listed are found much farther down Marcy, most of them quite down to the valley 3,000 feet below. *Oxalis Acetosella* is the dominant one, just as it is in the similar fir forest on the top of Slide Mountain in the Catskills, which has no alpine vegetation.

A comparison with the forest floor herbs found at the lower limits of the pure fir shows that *Cornus canadensis* is there the dominant herb, here replaced by *Oxalis Acetosella. Solidago macrophylla* in both places is common, and *Linnæa* and *Chiogenes* in both places make up a fair proportion of the vegetation. But some other herbs that are in the list on page 206 have not gone up to the edge of the forest, as the wood-sorrel, bunch berry and creeping snow-berry have done. Certain herbs of the fir—and lower down of the spruce—forest, at home in quiet shady places, their roots in a sponge of moss and scarce feeling the terrific winds that blow over the mountain, may as we shall see presently, go out over the bare summit changed in stature, often in color, and in nearly always habit, but still persisting and fruiting. Yet the plants typical of the summit, played upon by all the forces of an apparently uncongenial habitat, do not meet the conditions of the region below timber line well enough to be found there. The single exception is the bog at Lake Tear, already described. To the discussion of the plants of the summit there will be noted the amount and success of this invasion of purely alpine vegetation by these lowland plants. The evidence is all that it is the alpine plants that are isolated and being gradually crowded by these invaders.

The invertebrates of the marginal dwarf forest (fig. 7 in Part I) (Field Station *c*) are represented by a single collection. This included certain insects taken on wing near the tops of the trees, such as black fly, *Simulium hertipes* Fries (?), and two syrphids which were taken hovering among the balsam branches, *Syrphus ribesi* Linn. and *Melanostoma obscurum* Say, and the fly, *Bibio xanthopus* Wied., a characteristic species which hovers in the sun about the margins and over the surface of the dwarf forest. In a warm sunny moment a loud buzzing attracted attention to several horntails, of two species, *Sirex cyaneus* Fab. and *Urocerus albicornis* Fab., which were flying about among the branches, while from the moss and rotten wood of the forest floor was taken an earthworm (*Enchyatrid*), spider, *Tmeticus armatus* Bks., a myriopod, *Conotyla fischeri* Ck., the pupa of a beetle, tipulid larvæ *Tipula,* near *Ignobalis* Low., and small ants, *Leptothorax* (*Mychothorax*) *acervorum* Nyl., subsp. *canadensis* Prov.

Very little is known of the habits and habitats of most of the above listed species. The larva of *Sirex cyaneus* feeds upon the wood of spruce, fir, and hemlock. These are thus distinctly forest species. The larvæ of allied species of *Bibio* live in forest humus. It seems probable on the whole that the collection is distinctly of forest inhabitants.

While it was shown in Part I that timber line is a quite definite thing on the mountain, it was also noted that trees occur in depressions and ravines above it and therefore extend the habitat of forest animals well above 4,900 feet. While these animals live in the dwarf forest, it should not be ignored that they are within easy reach of abundant food, for near them, on the bare summit of Marcy are numerous plants with edible fruits such as blueberry, crowberry, cranberry, etc. Blueberries are eaten by the junco (Judd,[21] p. 81), white-throated sparrow (loc. cit., p. 72) and the Canada grouse (Judd,[22] p. 39). Forbush[23] (p. 10) lists the crowberry, *Empetrum nigrum,* and the bunch berry, *Cornus canadensis,* as plants whose fruits are attractive to birds. The latter plant is found above as well as below timber line. He also notes (loc. cit., p. 15) three species of blueberries, including two species found on Marcy, associated with these low conifers: dwarf blueberry, *Vaccinium cæspitosum* and *Vaccinium canadense.* The dwarf cranberry, *Oxycoccus Oxycoccus*, is listed by Forbush[24] (p. 376) as a plant with fruits edible for birds. McAtee[25] (p. 188) includes the dwarf blueberry in his list of plants useful in attracting birds.

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[21] Judd, S. D., "The Relation of Sparrows to Agriculture," U. S. Biol. Survey Bulletin 15, pp. 1–98, 1901.

[22] Judd, S. D., "The Grouse and Wild Turkeys of the United States and Their Economic Value," U. S. Biol. Survey Bull. No. 24, pp. 1–55, 1905.

[23] Forbush, G. H., "Plants that Attract and Shelter Birds and some that Protect Cultivated Fruit," Mass. State Dept. of Agr. Dept. Circular 13, pp. 4–29, 1919.

Little animal life was noted about these dwarf forests during the few days of observation, but birds and mammals, especially those that conceal themselves on the approach of man, could very easily be overlooked here, and it was almost impossible in walking through the growth to flush or "jump" any animal in it. No vertebrate was found that appeared to prefer the stunted to the taller forests lower down. The species noted were junco, myrtle warbler, chestnut-sided warbler, *Dendroica pennsylvanica*, swamp sparrow, *Melospiza georgiana*, and white-throated sparrow, *Zopotrichia albicollis*. A number of each of the first two were seen, but only one each of the others, except the last which was heard only. Eaton[26] records the following birds from altitudes where this Krumholtz exists: Junco ('14, p. 407); white-throated sparrow ('10, p. 47); pine siskin, *Spinus pinus* ('14, p. 279); myrtle warbler, *Dendroica coronata* ('14, p. 407); black poll warbler, *Dendroica striata*, and Bicknell's thrush ('14, p. 523); and found pine siskins breeding in large numbers near the peaks of Mount Skylight and Mount Marcy. Since the last named species prefers conifers for nesting, it undoubtedly used these stunted trees, the only ones in their breeding area noted by Eaton.[27] Colvin (loc. cit., p. 371) reports footprints of raven, *Corvus corax principalis*, at 5,000 feet and reports (p. 131) shooting a Canada grouse (probably *Canachites canadensis canace*) in the dwarf forest on Mount Skylight. It is probable that there are many of these grouse on Mount Marcy at present; guides testify to this.

About a dozen mouse traps left out for two nights in this low tree growth resulted in getting one red-backed mouse in a dense thicket of conifers near Station *d*, where the trees were about two and a half feet high. Mr. C. F. Batchelder in a letter writes that he found this species in the dwarf forest region on Mount Marcy. It is probable that the animal is permanently established here, at least in the lower part of the area, since the conditions favorable for the little animal are present almost everywhere in the dwarf forest. These conditions are well described by Batchelder[28] (p. 192) as follows: "One may look for it with some confidence in almost any large tract of wet ground that retains its moisture through the summer, but is not subject to serious floods, and which bears a growth of woods sufficiently heavy to afford a dense shade, so that the ground beneath, and the roots of the trees, are covered with a deep carpet of sphagnum. . . . One of the most evident peculiarities of such a spot as this, in Southern New England, is that dense shade and abundant evaporation maintain a temperature during the hottest summer weather that is far below that of the surrounding country." There was food in abundance for red-backed mice in the adjacent alpine growth, consisting of (Merriam,[29] p. 271) berries, roots, and bark. The blueberries that are found abundantly in that region are very probably eaten extensively by the red-backed mouse and other animals of the Krumholtz.

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[24] Forbush, G. H., "Useful Birds and their Protection," Mass. State Board of Agr., p. 1–451, 1913.

[25] McAtee, W. L., "Plants useful to Attract Birds and Protect Fruit," Yearbook Dept. Agr. for 1909, pp. 185–196, 1909.

[26] Eaton, G. H., "Birds of New York," Memoir 12, Part 2, New York State Museum, pp. 1–719, 64 plates, 1914.

[27] Black poll warblers were found breeding near the summit of Mount Marcy and other high mountains nearby (Eaton, loc. cit., p. 418).

[28] Batchelder, C. F., "Some Facts in Regard to the Description of Certain Mammals in New England and Northern New York," Proc. Boston. Soc. Nat. Hist., Vol. 27, pp. 185–193, 1896. See also Batchelder, C. F., "An Undescribed Shrew of the Genus *Sorex*," Proc. Biol. Soc. Washington, Vol. 10, pp. 133–134, 1896.

No other mammals were found in the region of stunted trees, but at one place a bed or "form" was found, with droppings beside it, indicating the presence of the varying hare, *Lepus americanus virginianus* (Harlan). Guides informed us that hares are common in this region. Colvin (loc. cit., p. 130), however, thinks that the varying hares taken on Mount Marcy are different from those found by him elsewhere in the Adirondacks. He says (p. 370) that the range of the species does not appear to be above 5,000 feet, and he mentions in particular the taking of one on Whiteface Mountain at 4,900 feet. Evidently this region gives a favorable habitat for the species, which prefers (Seton,[30] p. 627) a growth, "so dense that the fox, the lynx, and the wolf have no chance in open chase," and where they have open spaces for sun-baths.

No tracks or other signs of deer were noted in this low conifer growth, but deer are found here at times according to the testimony of guides. Colvin (loc. cit., p. 368) found the fisher, *Martes pennanti pennanti* (Erxleben), in the dwarf forests on Mount Marcy, where, he says, they hunt hares. Batchelder, in a letter, states that the masked shrew occurs here, as elsewhere on the mountain.

ALPINE ZONE 4,920–5,344 FEET.—The summit of Marcy is without forest covering, although there are stunted and gnarled trees scattered all over the mountain-top in protected places. The vegetation, other than trees, is made up of a group of alpine, sub-alpine and other species that are constantly subject to destruction, not only by climate, but by sliding boulders and slabs of rock. The local erosion cuts small gullies (fig. 19) through existing vegetation, and often retards revegetation of older erosion sites. On all the steeper slopes of the mountain above timber line are found large areas where vegetation is putting up a losing fight to cling to the side of the mountain. Some ancient and local group of plants, perhaps surrounding a dwarf tree (16–20 inches high) that may be 65 years old, will, during a spring thaw, be quite suddenly wiped out, leaving the naked site to be subsequently invaded. A host of pioneers then come and make ready the conditions that will support the climax vegetation which stable erosion conditions show to be the final type in the alpine zone (fig. 16).

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[29] Merriam, C. H., "The Mammals of the Adirondack Region," New York, pp. 1–316, 1886.

[30] Seton, E. T., "Life Histories of Northern Animals," New York, Vol. 1 and 2, pp. 1–267, 1909.

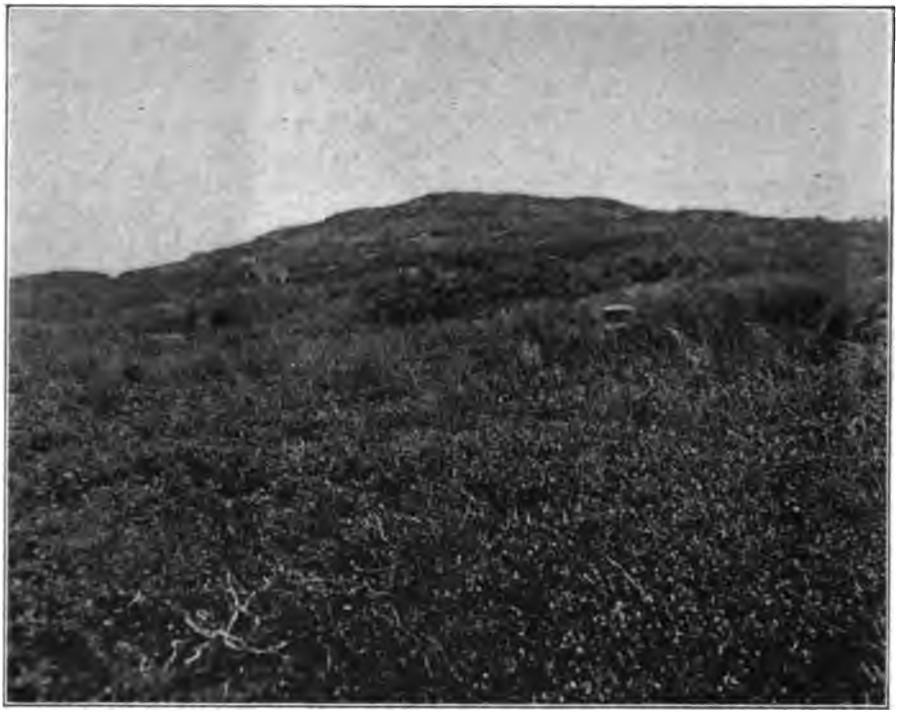

FIG. 16. Climax vegetation in the apine zone.

Upon this conception much of the vegetation of the mountain-top is in a constant state of flux, and it might be difficult or impossible to describe or conjecture what the ultimate type of vegetation would be, nor the steps that lead to that fulfilment. Fortunately there are many less steep places with few chances of destruction overtaking them, and in such is developed to perfection the typical alpine vegetation. But the accomplishment of this state is a tremendously slow and precarious process, and cases of arrested development are only too common. The chances of a rock slide many feet above such a vegetation climax, diverting a rivulet and thus drying up the site, or smothering with sand the edges of it, and all the fortuitous accidents that exposure to terrific winds, snow, and fogs and temperature (June 5, 1919, at the summit the sun temperature out of the wind was 94°; on August 21, at the camp, 4,300 feet, it was 42°), these and other accidents all make the final climax type of vegetation on the mountain top common enough on less steep places, but by no means so common over the whole mountain as it is on Mt. Washington.

The typical vegetation of this region above timber line shows certain well-marked characteristics, has certain kinds of plants always in it, and has quite definite stages in its development. So much of the mountain top is bare rock or loose slabs or boulders, all the soil is from the decomposition of such material, described elsewhere in this paper, that the earliest stages of vegetative covering are necessarily based upon the occurrence of this soil and a suitable water supply. To go one step backward, the organisms that help to break down this rock, and which cover many of them, are the real pioneers in the beginning of the vegetative climax. On many rocks otherwise quite bare, are to be found *Umbilicaria pustulata,* followed often by a tiny accumulation of mineral soil and then the mosses, *Andreæa petrophila* and *Polytrichum strictum.* The two latter often make quite considerable patches along the edges of great, bare boulders, catching small accumulations of soil and adding to such tiny pockets, by their own decay, a nucleus for the establishment of other plants. Where this accumulation of soil goes on long enough to become an inch or two deep and there is available water, we have a largely mineral soil, almost invariably occupied by the deer-hair, *Scirpus cæspitosus* (fig. 17). So common are the conditions that sustain

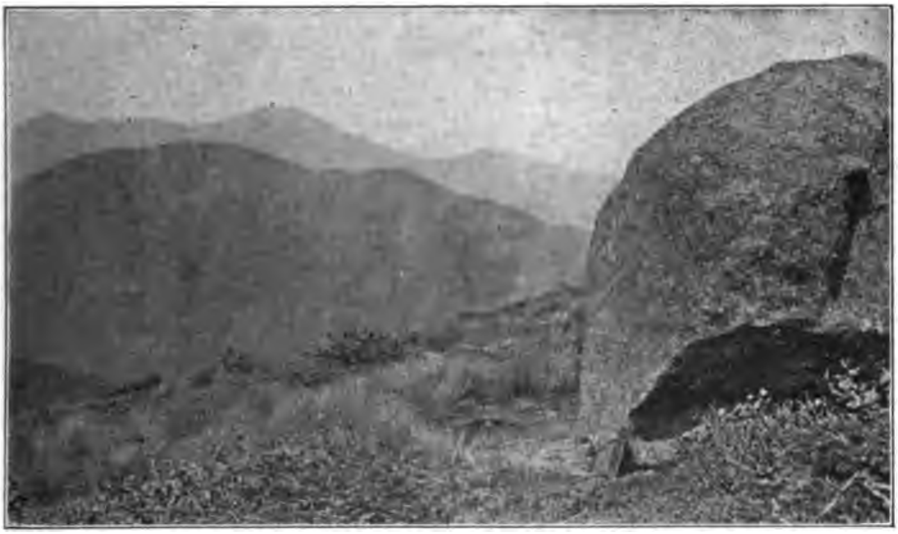

FIG. 17. Early stage in succession in the alpine zone. Deer-hair, *Scirpus cæspitosus,* showing zonation around a seepage spot.

this sedge that it almost appears as if it were the commonest plant of the region, its golden-yellow tips being conspicuous also in many other conditions than this one in which it is apparently the pioneer. Often growing near or on it, and due perhaps to the decomposition of successive generations of it, are found *Cladonia rangiferina* and *Sphagnum acutifolium*. One of the most characteristic features of the mountain-top are the small or large cushions of this moss and lichen fringed by *Scirpus cæspitosus*, and supplying a water soaked environment for the more permanent plants that come after. Sometimes with the *Scirpus cæspitosus*, or alone in similar conditions, *Arenaria grœnlandica* is to be found. Both of them are to be considered pioneers, as the climax type of vegetation hardly ever includes them and grows on an acid substratum which these plants do not need and rarely tolerate.

The stage following the accumulation of the moss-lichen cushion is followed by *Vaccinium uliginosum*, *Empetrum nigrum* and *Oxycoccus Oxycoccus*. Where the water supply is fairly near and copious, these plants grow luxuriantly and are normally colored, but on drier sites they are reddish or coppery and appear half starved, with poor shriveled fruits. Other plants growing in such places are, in the order of their frequency:

Ledum grœnlandicum
Vaccinium cæspitosum
Agrostis borealis
**Cornus canadensis*
**Trientalis americana*
**Betula papyrifera*, stunted, not over 1 ft. high
Lycopodium Selago
Potentilla tridentata
Chamædaphne calyculata
**Unifolium canadense*
Solidago Cutleri
Vaccinium canadense

This is fairly typical of the region just above the timber line, and in such places, and elsewhere over the mountain-top will be found stunted trees, about 15 inches high of *Picea mariana*, and of the fir, chiefly the latter. These are often half smothered by the dense cushion of sphagnum moss and the plants growing in it, and it is in the "protection" of these trees that most of the plants starred in the list grow. They belong in the forest below timber line and out on the bleak summit they usually, but not always, are found in the protection of these dwarf trees in ravines.

The occurrence of the black spruce here at 4,920 feet elevation, and only above timber line, where it is common quite up to the summit, is peculiar. The same thing occurs on Mt. Skylight, where we collected it only above 4,800 feet, and on Mt. McIntyre, where our records show it as not below 4,700 feet. Diligent search for cones of this spruce on all three mountains was rewarded only on Mt. Skylight, where, at 4,800 feet, a single tree, about 6 feet tall and in a locally protected place, was covered with cones. The black spruce is considered by some botanists merely an ecological variation of red spruce, *Picea rubens,* a stunted form occurring in bogs. In truth the distinction is not sharp and the two trees may readily be confused. But why should black spruce grow in the bogs at lower elevations (it does not grow in the Lake Tear bog at 4,320 feet), and then reappear on the summits above timber line? It is also found, according to Mathews, "Field Book of American Trees and Shrubs" (Putnam, 1915), on Mt. Katahdin, Maine, at 5,215 feet. It seems that this tree must be added to the list of alpine plants which are restricted to the zone above timber line and to certain bogs below it. Such plants here find an environment sufficiently rigorous to keep out most competitors and to delay the migration which has eliminated them from the more favorable places. Unquestionably they are relics of a colder flora following the ice, and, this study indicates, are subject to steady encroachment by the lowland plants to-day.

The rather meagre list of plants characteristic of this alpine zone, that is, just above timber line, could be greatly extended by only a slight rise in elevation. From 4,920 feet up to the summit at 5,344 feet, there are many hundreds of acres, sometimes pure rock slabs nearly bare of vegetation, some few deep ravines with trees in them which reach only to the height that the protecting rock keeps off the winds, some nearly level alpine fell-fields where the flora is more static than elsewhere and alpine species are best developed, and many steep slopes where destruction of local habitats goes on with rapidity and effectiveness. Depending on location and drainage, protection from wind and snow cover, there are acres of this climax type perfectly developed, and many others in the stages of development which have been indicated. At slightly higher elevations (5,050 ft.) and up to the summit, *Diapensia Lapponica* and *Rhododendron Lapponicum* appear in sufficient quantities to be a noticeable percentage of the vegetation.

Two well-marked and rather distinct variations of the typical alpine zone of the mountain demand notice, not alone for their curious assemblage of plants and animals, but because in them species were found not before recorded from above the timber line. These two localities are:

I. Dwarf birch meadow at 5,250 ft.
II. Meadow on S.E. side of mountain at 5,100 ft.

I. *Dwarf Birch Meadow.*—The meadow which we have named for this shrub, and it is the only place on the mountain where the plant was found, is about a quarter of a mile from the summit and on the northeast side of the mountain. It is an incipient glacial cirque, the only cirque on the mountain. On June 5, 1919, a large part of it was covered with snow deep enough and packed enough to walk over, and the margins, for 10–15 feet, fringed with a nearly exclusive growth of dwarf birch, *Betula glandulosa,* then in full flower (figs. 18 and 19).

During our second visit to this meadow in August it was found that the part uncovered by the melting snow consists almost exclusively of *Calamagrostis canadensis,* and not quite so common *Deschampsia flexuosa* and *Carex oligosperma.* This coarse turf, one of the ingredients of which is the same as for the bog at Lake Tear, is dotted with other plants. Many of these are apt to be partly smothered by grass, especially by *Calamagrostis canadensis.* The secondary species in this turf are, in the order of their frequency:

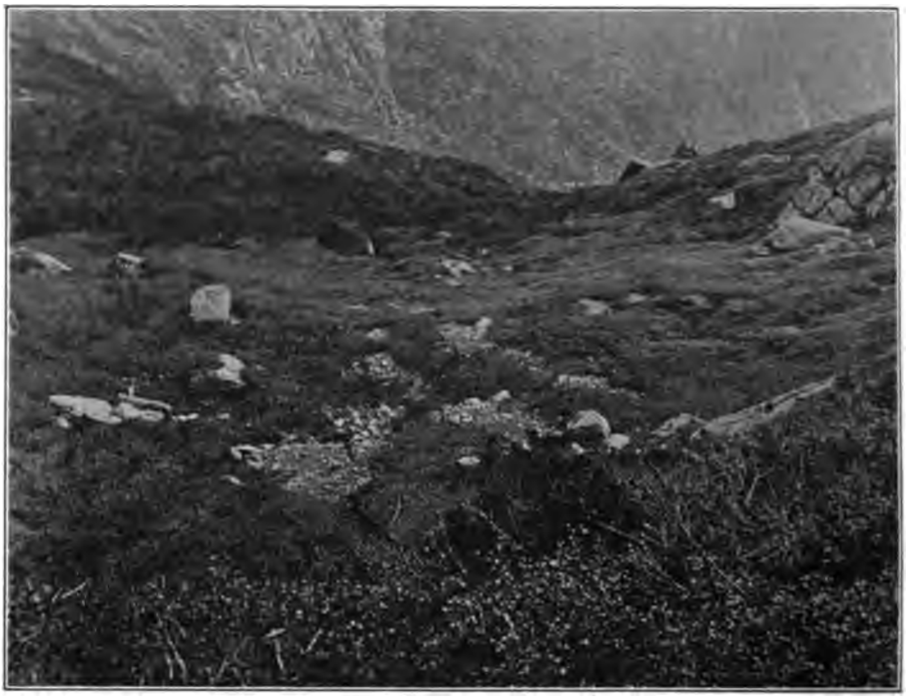

FIG. 18. Dwarf Birch Meadow from above, showing fringe of *Betula glandulosa* in the foregroung. This meadow contains many plants of lower elevations which are invading the alpine zone.

**Gentiana linearis*
Potentilla tridentata
Vaccinium cæspitosum
Vaccinium canadense
**Viola pallens*
**Rubus* (trailing species, no flowers or fruit)
**Spiræa latifolia*
Ledum grœnlandicum
Diapensia Lapponica
Rhododendron Lapponicum
Eriophorum callithrix
Lonicera cærulea
**Houstonia cærulea*
Lycopodium Selago

The occurrence of those species starred in the list, together with *Calamagrostis canadensis,* which is a dominant plant in the meadow, is another illustration of the encroachment of plants normally at home at much lower elevations, into the alpine zone. This meadow at 5,250 ft., near the summit of Marcy, and with a northeast exposure which subjects it to the winter winds from that quarter, sustains a fair percentage of plants that might not be expected to survive the rigorous conditions under which typical alpine species grow. *Calamagrostis canadensis* particularly, as the dominant turf grass, very luxuriant and fruiting freely in a short growing season to which its wide distribution at lower elevation would not seem to fit it, is a conspicuous example of what is true of so many other herbs on Mt. Marcy. Of course these comparatively lowland, or at least not alpine plants, are not as yet completely crowding out the true alpines here, except *Calamagrostis canadensis,* but they form a respectable part of the vegetation, and, surrounded by a thicket of *Betula glandulosa,* a true alpine shrub, the inhabitants of this upland meadow form an interesting study. For, isolated in this meadow are enough lowland species, one of them a practically dominant grass, to give a distinctly different aspect to the meadow from that of the

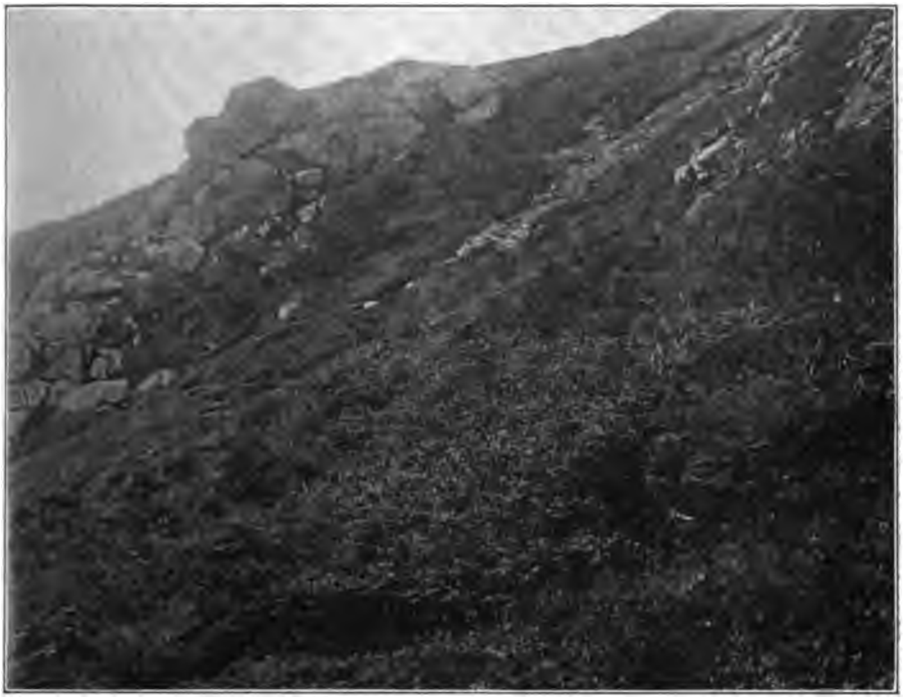

FIG. 19. Looking across Dwarf Birch Meadow, showing incipient cirque character and a gulley. Typical pocket of dwarf fir in a depression in foreground.

surrounding alpine vegetation. The isolation of these lowland species relatively so far above timber line, is matched at only one other place observed by us, on the southeast side of the mountain.

This basin, protected from winds, is particularly favorable for animals from lower altitudes, when once the snow has melted. The collection of invertebrates from this cirque include: the spiders *Clubiona,* and *Pardosa nigripalpus* Em., a staphylinid beetle *Acidota subarinata* Er., a bug *Clastoptera obtusa* (Say), jassids *Philænus spumarius* L., *Deltocephalus sayi* Fh. and *affinis* G. and B., a plant louse, the grasshoppers *Podisma glacialis glacialis* Scudd., *Melanoplus atlanis* Riley and *Cammula pellucida* Scudd., the butterfly *Eurymus pholadice* Godt., and the ants *Formica fusca* L. var. *algida* Wheeler, *Camponatus herculeanus* L. subsp. *ligniperda* Latr. var. *noveboracensis* Fitch. Specimens of *Bombus* were seen which were not taken. Here we see the upward extension of lowland species as in the case of the plants. The jassid *Deltocephalus affinis* is infested with a Dryinid parasite.

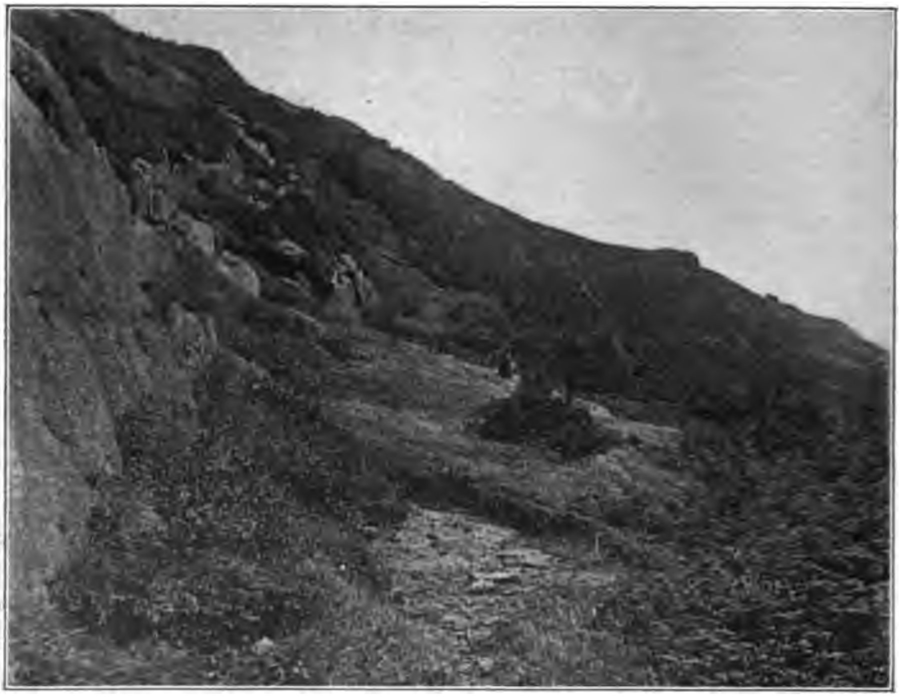

FIG. 20. Meadow on southeast slope at 5,100 feet, containing many lowland plants invading the alpine zone.

II. *Meadow on Southeast Side of the Mountain at 5,100 Feet.*—While the dwarf birch meadow shows some examples of the intrusion of lowland species through the alpine flora, the meadow on the southeast side of the mountain is remarkable for such intrusion. The meadow is about 300 feet long and 20–40 feet wide, rather steep, and faces south. It is northeast of where the trail from Ausable Lakes reaches timber line, and near the base of a large landslip slope that leads directly to the summit. On the west or mountain side the meadow is faced by a steep rock cliff 20–30 feet high, with little or no vegetation on it, except in crevices. On the lower side the meadow is fringed by fir trees, which are themselves bordered, toward the center of the meadow, by alder, *Alnus alnobetula,* a shrub not uncommon elsewhere in the alpine zone. A small rivulet comes out from the cliff about half way up the meadow, and meanders into a small bog-like place scarcely 10 feet square and is then lost by drainage through the loose soil and rock which underlie the region (fig. 20). The topography suggests that the meadow is covered with deep drifting snow in winter.

As in the dwarf birch meadow, the dominant, almost exclusive plant, is *Calamagrostis canadensis* which makes a coarse, dense turf. Near the outer edges of this turf are patches, or sometimes a fringe of *Lonicera cœrula, Vaccinium uliginosum* or *Vaccinium cæspitosum, Chamædaphne calyculata, Ledum grœulandicum* and *Spiræa latifolia.* Scattered through the turf are patches of *Deschampsia flexuosa* and along the edges of the cliff and other rocks are fringes of *Carex oligosperma,* which is rather uncommon. The latter sedge was noted in the bog at Lake Tear, but not elsewhere on the mountain. Other plants in this meadow, not arranged in order of frequency of occurrence, but with some notes on them, are as follows:

Linnæa americana
Oxycoccus Oxycoccus
**Houstonia cœrulea,* also the white flowered form.
**Cornus canadensis,* reddish colored and apparently unhappy.
Solidago Cutleri
**Solidago macrophylla,* common and luxuriant.
Lycopodium Selago
**Clintonia borealis,* not fruiting so freely as below timber line.
**Gentiana linearis,* common
Rubus sp. (the same as in dwarf birch meadow, and without flowers or fruits).
Ribes glandulosum
Potentilla tridentata, perfectly at home along edges of the cliff.
**Veratrum viride,* also scattered all over the summit.
**Doellingeria umbellata,* near the small bog-like center of the meadow.
Nabulus nanus, also scattered all over the summit.
**Blephariglottis dilatata,* this and the next near the bog-like center of the meadow.
Calamagrostis neglecta, also from Lake Tear, rare here.
**Viola labradorica,* rare and only a few seen.
**Carex intumescens,* rare.

There are a few scattered patches of shrubbery in the meadow where individuals are scarcely 2 feet high, and made up of *Amelanchier spicata* and *Viburnum pauciflorum,* the latter not before recorded from Mt. Marcy.

In the list those plants which are starred, as well as *Calamagrostis canadensis, Spiræa latifolia, Deschampsia flexuosa, Amelanchier spicata,* and perhaps *Viburnum pauciflorum,* are all to be considered as intruders from the lowland into a meadow that is well above timber line, and contains a fair percentage of alpine plants. This meadow is the most striking example of what is more or less true of all the summit of Marcy. Nowhere is the elevation great enough nor conditions unfavorable enough so that there is not this encroachment of lowland species up through the timber line and quite over the summit. The small number of true alpine species that are found on the mountain, the great scarcity of some of them, the crowding of the lowland species amongst them—all these make Mt. Marcy a very favorable site to study certain species on the altitudinal edges of their range. With a thousand feet greater elevation, the percentage of true alpines would certainly be much greater, as it is on Mt. Washington, and there would be nothing like the encroachments of lowland species up through the timber line. The summit of Mt. Marcy physiographically, and so far as a well defined timber line is indicative, has unquestioned alpine vegetation upon it. But this is composed of only a relatively small number of alpine plants. When the lowland plants, as in the case of *Viola labradorica, Solidago macrophylla, Clintonia borealis* and many others have a comparatively large exposure of leaf-blade and consequently a somewhat high transpiration rate, it is remarkable that they, as compared to *Ledum* and *Chamædaphne* and *Rhododendron Lapponicum,* and other plants well insured against a too vigorous transpiration rate should have monopolized so much of the summit of Marcy. Bonnier[81] mentions some interesting experiments he has made on the influence of an alpine environment upon plants from the lowland. The external and internal structure as well as the flowers of lowland plants grown at about 8,000 feet elevation became similar to those of alpine plants. He also found that the rate at which oxygen is given off and carbon dioxide taken up is two or three times as much in the higher altitude as in the lowland.

This particular meadow is of chief interest as illustrating, because of locally favorable conditions, such as the protection from the winds afforded by the cliff which borders its western edge, the determined encroachments of the lowland species wherever the opportunity for their survival presents itself. There are hundreds of locally favorable sites for this encroachment on Marcy, such as small ravines, pockets and cracks in the rock, and in nearly every one is to be found these lowland species often associated with a stunted fir or *Picea mariana.* It seems as if the factors that have made the timber line quite definite on the mountain have not created a barrier against the upward extension of those species noted as lowland ones. Except at Lake Tear, already discussed, *not one case of invasion from above downward* has been seen by us.

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[81] Bonnier, Gaston, "Le Monde vegetal," Ernest Flammarion, Paris, 1914. (See especially pp. 335–342.)

The collection of animals from this meadow include a daddy-long-legs, *Mitopus montanus* Bks., the spiders, *Lepthyphantes* and *Pardosa luteola* Em., the grasshoppers, *Podisma glacialis glacialis* Scudd., *Melanoplus atlanis* Riley, and *Melanoplus luridus* Dodge (only specimen taken on the mountain), a lygæid bug nymph, the jassid, *Deltocephalus sayi* Fh., the fly, *Bibio xanthopus* Wied., the bumblebee, *Bombus terricola* Kby., and the butterfly, *Argynnis atlantis* Edw. The Bibios were very abundant in the sun, hovering about the margin of the stunted trees and over them. A yellow butterfly, similar to *Eurymus* seen in the dwarf birch meadow, was seen but not captured. Two large brownish butterflies were seen but were not taken. The presence of the subalpine *Mitopus* here is of interest, illustrating the upward extension of a species from lower altitudes as in the case of the leaf hoppers, the butterflies, the bees, and the plants already mentioned.

As a record of what grows on the bare summit of the mountain, the following list of plants is presented. Most of the species in it were noted by Peck in his list in the Adirondack Survey of Colvin, already mentioned, or in his later paper in Bulletin 25 of the New York State Museum, 1898. A few recorded by him were not found, and some recorded by him we are inclined to doubt as inhabitants of the summit at present. A few, in bold-faced type, are here reported for the first time from the region.

FLOWERING PLANTS FROM THE ALPINE ZONE ABOVE TIMBER-LINE ON MT. MARCY[32]

†*Abies balsamea* (a, b, c)
Picea mariana
(*Abies nigra* of Peck's List)
**Juniperus communis*
Cinna latifolia (reported by Peck in 1898)
Cinna abundinacea (reported by Peck in 1898)

---

[32] Plants marked * are in Peck's lists but either do not grow there now or were not seen by us.

Plants marked † are obvious encroachments from below timber line. Names in **bold face type** were found by us but not reported by Peck. The letters in brackets, thus (a, b, c) after the names, show in which zones besides the alpine, each species was observed by us: (a)=lower limit of fir forest, 4,250 ft.; (b)=bog at Lake Tear, 4,320 ft.; and (c)=dwarf fir forest just below timber line, at 4,890 ft.

In the account of the vegetation of the summit of Marcy, Peck records that "about forty years ago the little moss plant, *Cassiope hypnoides,* was found by Dr. Parry growing in a sheltered depression on the summit of Mt. Marcy, but it does not

**Stipa canadensis*
    (*S. Richardsonii* of Peck's List)
 Agrostis borealis
    (Probably *A. canina* of Peck's List)
†*Calamagrostis canadensis* (b)
**Calamagrostis Pickeringii*
 Calamagrostis Langsdorfii (N. L. Britton, 1892)
 Calamagrotis neglecta (b)
 Savastana alpina
    (*Hierochloe alpina* of Peck's List)
†*Deschampsia flexuosa*
    (*Aira flexuosa* of Peck's List)
 Poa laxa
**Carex scirpoidea.*
**Carex trisperma* (reported by Peck in 1898)
**Carex canescens* (reported by Peck in 1898)
**Carex brunescens* (reported by Peck in 1898)
**Carex sterilis* (reported by Peck in 1898)
 Carex oligosperma (b)
**Carex vitilis* (?)
**Carex concolor*
    (*C. rigida Bigelovii* of Peck's List)
†**Carex intumescens** (a)
**Carex paupercula*†
    (*c. irrigua* of Peck's List)
 Scirpus cæspitosus
 Eriophorum callithrix
    (*E. vaginatum* of Peck's List)
 Juncoides parviflorum
    (*Luzula parviflora* of Peck's List)
 Juncus trifidus
**Juncus filiformis* (reported by Peck in 1898)
†*Veratrum viride* (b)

appear to have been found there since 1879." Diligent search by us, and by others for several years back for this plant has been unsuccessful. Furthermore none of the larger herbaria of the country has a specimen of Parry's from here. In fact it was on this report that *Cassiope hypnoides* was admitted to the Adirondacks by the manuals. The bulk of the Parry Herbarium is now at Iowa State College and Dr. L. H. Pammel writes that "I do not find that there are any specimens of this species from Mt. Marcy in it." In the herbarium of the Philadelphia Academy of Natural Sciences there is a specimen from "The Adirondack Mts." New York. Coll. J. V. H. MD. Date: July 1879. This specimen is from the herbarium of and appears to be collected by Joseph V. Haberer, a physician of Saquoit, N. Y. Dr. Haberer writes that his specimen of *Cassiope hypnoides* was collected on Panther Mountain and is in the herbarium of Hamilton College.

†*Unifolium canadense* (b)
†*Clintonia borealis* (a, c)
†*Streptopus amplexifolius*
**Streptopus roseus* (reported by Peck in 1898)
†*Blephariglottis dilatata*
(*Habenaria dilatata* of Peck's List)
Salix Uva-Ursi
(*S. Cutleri* of Peck's List)
Betula glandulosa
†*Betula papyrifera* (a, b, c)
Alnus alnobetula
(*A. viridis* of Peck's List)
**Alsine borealis* (reported by Peck in 1898)
Arenaria grœnlandica
Coptis trifolia (a, b)
†**Thalictrum polygamum**
Ribes glandulosum (a)
†*Spriæa latifolia* (b)
(*S. salicifolia* of Peck's List)
†*Rubus strigosus* (a)
**Rubus americanus* (reported by Peck in 1898)
Potentilla tridentata (b)
†*Sorbus scopulina*
(*Pyrus americana* of Peck's List)
†*Amelanchier spicata* (a)
†*Oxalis Acetosella* (a, c)
Empetrum nigrum (b)
†*Viola pallens*
(Probably *V. blanda* of Peck's List)
†**Viola labradorica**
**Epilobium angustifolium*
†*Cornus canadensis* (a, c)
Rhododendron Lapponicum
**Kalmia glauca*
Ledum grœnlandicum (b)
(*L. latifolium* of Peck's List)
Chamædaphne calyculata
(*Cassandra Calyculata* of Peck's List)
†*Chiogenes hispidula* (a, b, c)
Vaccinium canadense
(*V. pennsylvanicum* of Peck's List)
Vaccinium cæspitosum (b)
Vaccinium uliginosum (b)

Oxycoccus Oxycoccus (b)
†*Gentiana linearis* (b)
Diapensia Lapponica
**Melampyrum latifolium*
(*M. americanus* of Peck's List)
**Chelone glabra* (reported by Peck in 1898)
**Rhinanthus Crista-galli*
†*Houstonia cœrulea* (b)
†*Linnæa americana* (a, b, c)
(*L. borealis* of Peck's List)
Lonicera cœrulea (b)
†**Viburnum pauciflorum**
†*Trientalis americana* (b)
†**Doellingeria umbellata**
Solidago Cutleri
(*S. virgaurea alpina* of Peck's List)
†*Solidago macrophylla* (a, c)
(*S. thyrsoidea* of Peck's List)
Nabulus nanus
**Nabulus Bootii* (reported by Peck in 1898)

Of the 80 species in this list, 21 reported by Peck may have disappeared or at least were not seen by us, and 7 rather conspicuous plants, which such a careful botanist could scarcely have missed, have apparently come into the flora. Of these 7 it is significant that 4 are certainly encroachments from lower down the mountain, and that the others are not true alpine plants, although of northern affinity.

Taking the mountain top above timber line as a whole, we find that the species of lowland affinities that have come up through the upper limit of the forest number at least 30, that the true alpines are probably 23 species, which leaves about 23 which it is scarcely safe to assign to either group. So far as Marcy is concerned, the latter do not occur anywhere else except above the timber line, and a few at Lake Tear bog, but in other regions they are more generally distributed. Peck reported not more than 16 true alpine or subalpine species in 1879 and our studies indicate only a somewhat greater number. This mountain-top, with an alpine aspect, is so then, not wholly by virtue of the alpines on it, but by the encroachment of plants from the lowland, which in the conditions above timber line, assume quite different characters from their usual lowland ones; on the other hand the alpines have not been found invading the lower elevations. The mixture of these two elements and a third make up the flora of the summit.

The third element is one apparently neither alpine or lowland. So far as Marcy is concerned, the plants comprising it occur almost exclusively above timber line, and some in the bog at Lake Tear, but in other parts of the northeastern states they are bog plants or those of open, rocky places, but not necessarily inhabitants of regions above timber line. Among these are *Calamagrostis neglecta, Carex oligosperma, Coptis trifolia, Ribes glandulosum, Ledum grœnlandicum, Chamædaphne calyculata, Vaccinium canadense, Oxycoccus Oxycoccus,* and *Lonicera cœrulea.* These and perhaps a few others, while they are common plants on the summit, do not appear to have the significance ecologically that the contrasting alpine and lowland elements certainly have in the vegetative covering of the summit of Mt. Marcy. As to the factors that control the disappearance of well-known plants from the summit such as *Cassiope* and *Phleum pratense* not much is known. The latter was found by Peck but not seen again, and he reported that the orchid *Blephariglottis dilatata,* originally found there by him in 1879, had disappeared. We found it there in fair quantity in at least one locality above the timber line but failed to see *Phleum pratense.* There seem to be, in other words, many plants from the lowlands that come out over the summit of Marcy, survive a few seasons and then pass away.

The summit, so far as animals are concerned, may be considered as an elevated island of open in a sea of balsam forest. Viewed *from above* both of these openings in the forest, Lake Tear and Marcy, show clearly defined concentric zonation; about the lake this is nearly on the same plane, but on the mountain it is on successive elevations. The main animal habitats range from the extensive area of stable solid rock, supplemented by a large area of unstable loose rock in the avalanche region on the southeastern slope, onward through a meadow stage (fig. 16) to the heath or blueberry shrub stage, which may be considered the climax of the alpine area. The animals which live among the stunted balsam firs of the ravines and protected places have already been considered in the section on the dwarf fir forest. The three strictly alpine habitats are thus bare rock, meadow and the heath. The heath is apparently the main habitat of the invertebrates; the vertebrates apparently pay little attention to these minor differences. Local conditions have differentiated somewhat the meadow habitat, especially at two localities. One is in the cirque on the northeastern slope at about 5,200 ft., and called the dwarf birch meadow and the other is the grass meadow on the southeastern slope at about 5,100 feet, not far from the base of the extensive avalanche slope (fig. 19 and fig. 2 in Part I), both of which have been described above under separate headings. The dwarf fir trees and occasional prostrate black spruce have no doubt characteristic animals associated with them, but this problem was not given special attention.

Scudder[38] observes that in the White Mountains of New Hampshire the three zones, forest, krumholtz and alpine "correspond, in the characteristics of their inhabitants, to the Canadian, the Hudsonian, and the sub-arctic or Labradorian faunas."

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[38] Scudder, S. H., "The Distribution of Insects in New Hampshire," Final Rep. Geol. N. Hamp., pp. 331–380, 1874.

The miscellaneous collections of invertebrates which were taken above timber line will be listed first, and later those of special localities or habitats. At about 5,100 feet above timber line were taken two spiders, *Pardosa musicola* Em., and *Pardosa luteola* Em., and the carabid beetle, *Platynus supripennis* Say. These spiders are species of which Emerton[84] (p. 144) states, "Live on mountain tops down to and below the trees, in bogs in Maine, in New Foundland and Labrador." Other collections from above timber line included an ichneumon, *Lissonota punctulata* (Cress), the grasshopper, *Melanoplus atlanis* Riley, and the fly, *Bibio xanthopus* Wied., and a spider with an egg mass, *Pardosa musicola*. In a grassy area near the top of the mountain two specimens of the grasshopper, *Camnula pellucida* Scudd. were taken. At about 5,280 feet was secured a pair of copulating wingless greenish alpine grasshoppers, *Podisma glacialis glacialis* Scudd., the characteristic alpine grasshopper of the mountain. This is one of the few invertebrates previously recorded from the alpine area. Scudder[85] ('97, p. 100) records it from Marcy at 5,400 feet, an elevation greater than that of the mountain! In the White Mountains he records it frequenting the "close branches of the dwarf birch, *Betula nana* [*B. glandulosa*], and is rarely or never seen on the ground." He also records it from Chateaugay Lake, in the Adirondacks at 2,000 feet. A bumble bee, *Bombus terracola* Kby., was taken at about 5,000 feet. A specimen of the horntail, *Urocerus albicornis* Fab., was taken near the top of the mountain in a grassy area, where it had probably flown from some patch of dwarf forest.

Two series of collections from among the heath plants are worthy of special mention. At about 4,900 feet among the heath plants, *Vaccinium, Ledum,* and others, in the vicinity and above Field Station *d,* the following were collected: the spiders, *Pardosa luteola* Em. and *Pardosa diffusa* Em., *Pardosa uncata* Thor., the grasshoppers, *Chorthippus curtipennis* Harr., *Camnula pellucia* Scudd., *Podisma glacialis glacialis* Scudd., *Melanoplus atlanis* Riley, a tachinid fly, *Peleteria prompta* Meig., a syrphid fly, *Syrphus torvus* O. S. and two ichneumons, *Amblyteles funestus* (Crees) and *A. pectifrons* Cress, and the butterfly, *Polygonia faunus* Edw. At about 5,300 feet among blueberries and *Cladonia* the spiders, *Pardosa ulteola* Em. and *Pardosa musicola* Em., a daddy-long-legs, *Mitopus montanus* Bks., the greenish wingless grasshopper, *Podisma glacialis glacialis* Scudd., the grasshoppers, *Melanoplus atlanis* Riley and *Camnula pellucida* Scudd., the bug, *Mabis ferus* Linn., two jassids, *Deltocephalus sayi* Fh. and *affinis* G. and B., a beetle, *Lebia ornata* Say (var.), the cerambycid beetle, *Leptura canadensis*

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[84] Emerton, J. H., "Geographical Distribution of Spiders in New England," Appalachia, Vol. 13, pp. 143–159, 1914.

[85] Scudder, S. H., "Revision of the Orthopteran Group Melanopli (Acridiidæ) With Special Reference to North American Forms," Proc. U. S. Nat. Mus., Vol. 20, pp. 1–421, 1897; "The Alpine Orthoptera of North America," Appalachia, Vol. 8, pp. 1–21, 1898.

Fab. (the larva feeds on spruce), *Coccinella transversoguttata* Fab., a fly, *Bibio xanthopus* Wied., an ichneumon, *Pezomachus,* and an ant, *Formica sanguinea* Lats., *aserva* Forel. The presence of *Mitopus* above timber line, and also at our camp in the forest is worthy of mention. This phalangid was first recorded from the White Mountains. Mr. Nathan Banks, the author of the species, writes in a letter, "I have since seen it from Maine, several from Province of Quebec (about central part), and Nova Scotia, now yours from Mt. Marcy. Nothing is known of its habits, except that it is sub-alpine." And we may now also add alpine. It was also taken in the grassy meadow on the southeastern slope. It is probably, in the alpine area, mainly an inhabitant of the stunted balsam. The specimen of *Deltocephalus affinis* is parasitized by a Dryinid.

In summarizing the alpine invertebrates we observe that very little is known about certain species, so that no generalization can be based upon them. Others are well-known species of extensive geographic range and in no way peculiar or restricted to these mountain conditions. A few species are in this region mainly restricted to these alpine or bog openings. Faunistically these are the following: spiders, *Pardosa musicola* Em., *Pardosa luteola* Em., *Pardosa uncata* Thor., *Lycosa albohastata* Em., and the alpine grasshopper, *Podisma glacialis glacialis* Scudd.

If, however, we group these alpine species ecologically, as an alpine association, we may include not only the preceding species but also the following: *Melanophus atlanis* Riley, *Melanophus Femur-rubrum* DeG., *Camnula pellucida* Scudd., *Bombus terricola* Kby., *Bombus fervidus* Fab. As a marginal form, between the forest and the alpine open, is the fly, *Bibio xanthopus* Wied. Further studies should increase the number of species as well as a knowledge of their status in such conditions.

Special attention is called to the fact that the greatest lack in our knowledge of these alpine animals is of their life histories, the detailed relations to their environment, and the relation of these animals to one another—their community relations.

No evidence of permanent residents among vertebrate life were found by us in the alpine area, but some birds visit the region. A junco was seen near the summit, and Eaton ('10, p. 47) says that juncoes visit the top to feed on lunches left by tourists. At one time several barn swallows (*Hirundo erythrogastra*) flew over, showing no tendency to linger, and their presence was probably not due to any conditions at the mountain top. Colvin (loc. cit., p. 95) reports seeing hundreds of snow buntings, *Plectrophenax nivalis nivalis,* near the top in winter, and saw two eagles, very probably bald eagles, *Haliæetus leucocephalus leucocephalus,* fly up from near the mountain top. Eaton (loc. cit., p. 44) notes one flying over Haystack Mountain.

Mr. C. F. Batchelder in a letter states that he found four species of mammals on this barren peak region. These were: Red-backed mouse, *Evotomys gapperi gapperi* (Vigors), white-footed mouse, *Peromyscus maniculatus gracilis* Le Conte, masked shrew, *Sorex personatus personatus* Geoffrey, and the big-tailed shrew, *Sorex dispar* Batchelder (Batchelder, '96, p. 133 and '11). The latter was taken here in a rock crevice at an altitude of 5,300 feet.

Colvin (loc. cit., p. 368) observed a fisher, *Martes pennanti pennanti* Erxleben, on Mount Marcy in the winter and shows how this animal might frequent this region even in winter when he tells of their speeding out on icy rocks, and passing safely across glary surfaces of avalanche-swept mountain sides, when pursued by dogs.

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PLANTS AND ANIMALS OF MOUNT MARCY, NEW YORK, PART III

CHARLES C. ADAMS, GEORGE P. BURNS, T. L. HANKINSON, BARRINGTON MOORE,
AND NORMAN TAYLOR

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V. TREE DISTRIBUTION AND EXPOSURE

Above timber line[36] in the shelter of certain rocks are found compact groups of stunted balsam firs, while beside others is alpine vegetation. What is it that permits dwarf trees to become established in certain places and not in others?

In the Selkirk mountains of British Columbia Shaw[37] found that timber was lacking in the depressions above approximately 6,000 feet, but extended above this elevation on knolls and ridges. He explains this as due to late melting snows and black fungus which is left on the trees after the snow. It has also been shown by Cowles that in a number of places in North America snow beds and timber line are causally related. Bouget[38] working in the Pyrenees found mesophytic herbaceous communities of mixed lowland and alpine plants where the snow lies late, and trees on the ridges at the same elevations. Thus timber line in the Pyrenees, as in the Selkirks, runs higher on the ridges than in the depressions. Examples of lowland communities where the snow lies late on Mt. Marcy are described above in Part II under the "Dwarf Birch Meadow" and "Meadow on Southeastern Side of the Mountain at 5,100 feet" (ECOLOGY, Vol. 1, No. 3 pp. 220–226). Aside from these two examples, conditions on Mt. Marcy appear to be the reverse of those found in the Selkirks and in the Pyrenees, for on Marcy the trees push upward in the ravines, not on the knolls and ridges. But on Mt. Marcy there are no extensive slopes above timber line to collect snow, whereas in the Selkirks and Pyrenees masses of snow probably come down from above into the ravines, preventing the development of trees by avalanches and by occupying the ground late in the growing season. Hence on Mt. Marcy the trees extend to higher elevations in the ravines than elsewhere.

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[36] See definition of timber line as used in this study, ECOLOGY, Vol. I, No. 2, p. 72.

[37] Shaw, C. H. "Causes of Timber Line on Mountains," Plant World, Vol. 12, No. 8, pp. 169–181, 1909. "Vegetation and Altitude," Am. Naturalist, Vol. 43, pp. 420–431, 1909.

[38] Bougert, J. "De l'influence des neiges sur la repartition des differents végétaux a même altitude dans les zones elevees des Pyrenees," Rev. Gen. Bot. 30: 305–320, 1918. Bot. Gaz. 69: 533, 1920.

It has been supposed that the stunting of trees in arctic regions and on Mountains is due to the winds withdrawing moisture from the needles at times when the frozen ground prevents the roots from replacing this moisture. But recent work on the transpiration of conifers in winter has shown that "the winter transpiration losses from conifers are scarcely greater than those from the defoliated stems of broad-leaf trees."[39] It therefore appears that the winter winds may not be the only cause affecting tree distribution on mountains.

In considering the influence of wind on tree distribution in the alpine zone it is necessary first of all to know something of the winds to which the open places and the groups of stunted trees are exposed. Would not the direction of the shelter with relation to the wind play some part in permitting or preventing tree growth? Information on this question might throw light on the relation of wind to timber line. On Mount Marcy the prevailing winds are from the northwest and the west.

A map (fig. 21) of a portion of the summit above timber line was made by means of a rough plane table, compass and tape. The last was used only between stations, the size of the tree groups, open areas (alpine vegetation), and rock masses, being obtained by pacing. The direction of the winds to which each area is exposed was noted and recorded on the map by arrows. The survey was run along the 5,000 foot contour, starting at a point on the south trail where a metal plug marked "O 107" was found set in a rock dome. The point is marked ".07" instead of "O 107" in the lower part of the map (see fig. 21) where the contour makes a bend at right angles from a north-south to an easterly direction. (Figure 2 in Part I (ECOLOGY, Vol. 1, No. 2, p. 74) was taken at approximately the point ".07," looking north. The main map shows south, west, and northwest exposures; the small insert map gives a typical case of north, northeast and east exposures. In addition to showing exposure to wind the map gives a general idea of the relative proportions of dwarf trees, alpine vegetation (marked "open grasslands" on the map), and bare rock in the lower part of the alpine zone. The proportion of dwarf trees is less above 5,000 feet. Collections of animals, listed further on, were made along the survey line.

In general, the degree of shelter required against south, southwest, and west winds is less than that required against northwest winds. The insert may indicates that easterly winds are also of lesser importance. It will be noticed that on the map a large proportion of the open areas are exposed to the northwest winds, while not a single tree group shows exposure to winds from this direction. On the north side of the mountain, however, not included in the map, is a large body of stunted balsam firs extending well above timber line and exposed on the northwest. But these trees occur in deep, moist ravines almost certainly filled with snow in winter.

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[39] Weaver, J., and Mogensen, A. "Relative Transpiration of Coniferous and Broad-leaved Trees in Autumn and Winter," Bot. Gaz. 68: 393–424, 1919.

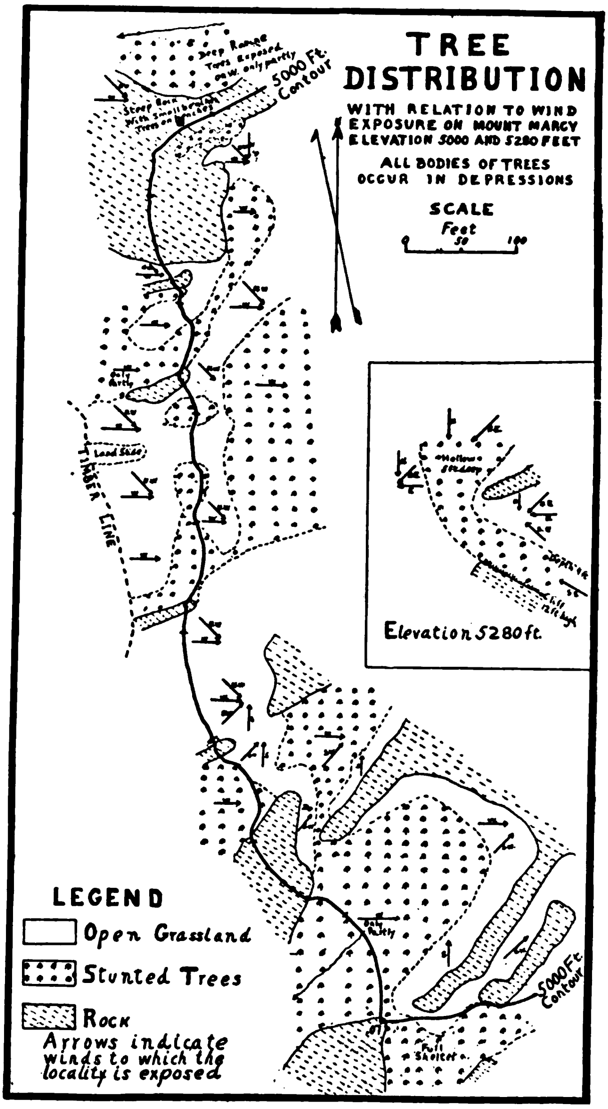
TREE DISTRIBUTION
WITH RELATION TO WIND EXPOSURE ON MOUNT MARCY ELEVATION 5000 AND 5280 FEET
ALL BODIES OF TREES OCCUR IN DEPRESSIONS
SCALE
Feet
0 50 100
Deep Range Tops exposed on W. only partly
5000 Ft. Contour
Steep Rock With small dwarfed Trees on ledges
Timber Line
Land Slide
Only Partly
Elevation 5280 ft.
Hollow Swamp
.07
Full Shelter
5000 Ft. Contour
LEGEND
Open Grassland
Stunted Trees
Rock
Arrows indicate winds to which the locality is exposed

FIG. 21. Map showing distribution of vegetation with relation to wind exposure. The "open grassland" should be called alpine vegetation, and the number .07 near the bottom should be O107. Areas of stunted trees without arrows may have the tops exposed, but the trees themselves are fully sheltered.

The most striking fact noted during the mapping was that the trees are confined to the depressions.

The only exception, which tends to emphasize rather than to refute the rule, is an occasional flattened black spruce, *Picea mariana,* and balsam fir, *Abies balsamea,* hugging the ground in an opening. These prostrate trees, though not uncommon are by no means abundant, and illustrate in a striking manner the extreme precariousness of tree life outside of the depressions. As a general rule the height of the trees corresponds with the depth of the depression. The trees form a dense and uniform crown canopy at a certain level. Above this uniform canopy the leaders protrude. Only a few are uninjured, many of them are dead, and others are dead on one side. These leaders bear witness to the desperate struggle between the trees and the elements. The trees unceasingly endeavor to extend upward, the elements as steadily kill them back to a certain level. The injury to the partly killed leaders is on the northwest side in the majority of cases. Leaders fully exposed to the north, northeast and northwest winds invariably showed injury on the northwest. Trees on a southerly aspect (S. 22° W. to be exact) showed some injury from the west, a little from the south, but most from the northwest which must be due to the high winter winds sweeping around the mountain. This shows the power of the northwest wind.

Just how the wind acts upon the growth of the trees could not be definitely ascertained. It may be that the canopy level represents a line below which the force of the wind is so lessened by the configuration of the ground that the trees are not injured. Or it may be, and this seems more probable, that the canopy level corresponds with the depth of the snow in winter; the leaders extending above the snow being injured and eventually killed. Variation from year to year in the depth of the snow above a certain level represented by the tree canopy would account for some of the leaders being still uninjured. The nature of the injury does not seem to indicate a high degree of mechanical or "sand blast" action which would come from particles of ice driven with great force. There is none of the etching out of the wood such as is found on the high mountains of the west. Undoubtedly much of the injury is due to mechanical action of a less intense form, but some of it may also be due to drying out by the sun and wind above the snow.

From the area of stunted trees shown at the base of the map (fig. 21) and along its margin were taken the spider *Pardosa musicola* Em., the lady bird beetle *Coccinella transversoguttata* Fab., the leaf hopper or jassid *Oncopsis fitchi* VanD., the alpine wingless grasshopper *Podisma glacialis glacialis Scudd.,* and the grasshopper *Melanoplus atlanis* Riley. Along the survey line, about 400 feet to the northwest in an open grassy area was taken the spider *Pardosa musicola* Em., the grasshopper *Camnula pellucida* Scudd., and *Melanoplus atlanis* Riley, the fly *Bibio longipes* Leow., and the ant *Formica sanguinea* Latr., subsp. *aserva* Forel. At about 425 feet northwest of the starting point was a deep crevice in the rock, facing west and with dripping wet sides. Near this crevice was an area of sedges, *Vaccinium* and *Cladonia,* with prostrate black spruce, and about a foot of sand and humus soil. Here was taken the spider *Pardosa musicola* Em., the grasshoppers *Melanoplus atlanis* Riley, and *Circotettix verruculatus* Kby., the bug *Lygrocoris diffusis* Uhl., the fly *Bibio xanthopus* Wied., and the ant *Camponotus herculeanus* L., subsp. *ligniperda* Latr., var. *noveboracensis* Fitch. At about 900 feet along the survey line a large ravine is encountered. The general character of this area is shown in figure 3, Part I, p. 75. The collections from the vicinity included the spider *Pardosa distincta* Black., *Lycosa albohastata* Em., the grasshopper *Melanoplus atlanis* Riley, a bug *Nabis subcoleopterous* Kby., a caterpillar, an ichmeumon *Amblyteles funestus* (Cress.), a muscid fly *Pollenia rudis* Fab. (infested with a fungus), the fly *Bibio xanthopus* Wied., and the ant *Formica sanguinea* Latr., subsp. *aserva* Forel. The only specimens of the large grasshopper *Circotettix* were taken along this line. They show a preference for bare rock, as in the specimens taken at the beginning of this survey line, when their hovering flight was observed. The fly *Pollenia* is reported as a parasite on earthworms.

VI. INFLUENCE OF ALTITUDE ON TREE GROWTH

The Mount Marcy region is particularly favorable for studying the influence of altitude on tree growth because one tree species, balsam fir, is found from the lower elevations almost to the summit. Since, however, this study is concerned primarily with timber line and the habitats just above and below it, the records of tree growth were taken at the following points: (1) The lower limit of the pure fir forest, 4,250 feet; (2) at timber line, 4,890 feet, on the extreme upper edge of the continuous forest just below the alpine vegetation; and (3) in the tree groups above timber line at 4,980 feet, with a few at 5,000 and at 5,200 feet.

The growth figures were obtained by means of a Swedish increment borer twelve inches in length. With such small trees it was possible to take cores clear through from one side of the tree to the other. This enabled correction to be made for trees in which the rings were wider on one side of the trunk than the other. The boring did not always strike the centre, but this made no difference since care was taken not to include measurements which were off the radius. It was not practicable to secure figures on total age, nor are such figures essential in determining the rate of growth. Most measurements were taken at a height of twenty centimeters above the ground, the lowest point at which the increment borer can readily be manipulated. In some cases the measurements were taken at thirty centimeters, in exceptional cases higher. Since the total age was not secured the height of the core was of importance chiefly in avoiding the butt swelling. Only dominant trees were taken. The width, in millimeters, of each ten years was measured in accordance with the usual forestry practice.

The accompanying curves (fig. 22) show graphically the rate of growth in diameter inside bark of balsam fir at the different elevations. These curves were constructed by the usual forestry method, plotting the points for each decade, and averaging these points. A remarkable feature was the regularity with which the curves passed through the average points, it being unnecessary, except in minor cases, to "smooth off" the curves by ignoring points out of line.

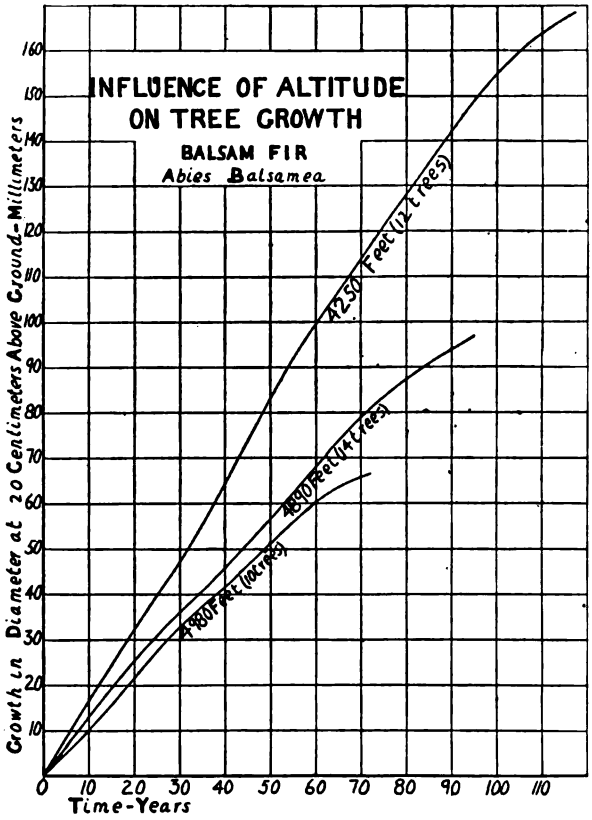

FIG. 22. Rate of growth in diameter inside bark of balsam fir at different altitudes on Mt. Marcy.

Table 5 gives the diameter inside bark at each ten year period, taken from the curves, and also the average annual growth for each decade. It will be noticed that the rate is not uniform throughout the life of the tree. Table 6 gives the age at each centimeter of diameter inside bark, taken from the curves.

TABLE 5. *Growth of balsam fir in diameter inside bark at different altitudes*

Time, Years	Diameter inside bark at each 10 year period, millimeters			Average annual growth in each 10 year period, millimeters		
	At 4,250 ft. elevation	At 4,890 ft. elevation	At 4,980 ft. elevation	At 4,250 ft. elevation	At 4,890 ft. elevation	At 4,980 ft. elevation
10.....	16.8	13	10	1.7	1.3	1.0
20.....	32	25.3	21.5	1.5	1.2	1.2
30.....	47	36	32.7	1.5	1.1	1.1
40.....	64	45.7	41.5	1.7	1.0	.9
50.....	83	56.6	51.2	1.9	1.1	.9
60.....	99.5	68	60.3	1.6	1.1	.9
70.....	114	79	65.7	1.5	1.1	.6
80.....	128	87.4		1.4	.8	
90.....	142	94		1.4	.7	
100.....	154.8			1.3		
110.....	164			.9		

TABLE 6. *Age of balsam fir at each centimeter of diameter inside bark at different altitudes*

Centimeter inside bark	Age, years		
	At 4,250 ft. elevation	At 4,890 ft. elevation	At 4,890 ft. elevation
1...............	6	8	10
2...............	12	16	19
3...............	19	24	28
4...............	25	34	38
5...............	32	44	49
6...............	38	53	60
7...............	43	62	
8...............	48	71	
9...............	54	84	
10...............	60		
11...............	67		
12...............	74		
13...............	81		
14...............	89		
15...............	96		
16...............	105		

The decrease in rate of growth is not in exact ratio with increasing altitude. The average annual growth for the first 60 years at each of the three elevations represented in the curves is as follows:

At 4,250 feet, average annual growth of first 60 years .... 1.65 mm.
At 4,890 feet, average annual growth of first 60 years .... 1.13 mm.
At 4,980 feet, average annual growth of first 60 years .... 1.01 mm.

Plotting these values we find that the decrease per unit of elevation is greater between 4,890 and 4,980 feet than between 4,250 and 4,890. It appears therefore that rate of growth diminishes with altitude, and that at a certain point (the beginning of alpine vegetation in this case) the diminution per unit of elevation becomes more rapid.

The curves show that the influence of altitude is exerted not only upon the rate of growth, but upon the longevity of the trees. It will be noticed that at 4,980 feet the growth rate drops off at 60 years. At timber line the rate continues for 70 years (68 to be exact), while at 4,250 the final drop in rate does not occur before 95 years, although there is a decrease after 50 years. Thus, at the higher elevations the trees not only grow more slowly but are shorter lived; on the other hand, decay seems to be more prevalent below timber line.

VII. Growth Forms of Plants

In considering the response of the vegetation above timber-line, it seems best to omit from our calculations several species credited to the region and either so rare or actually wanting now that they are scarcely of significance. The omitted species, for the purposes of sorting into the Raunkiær growth-form categories, are *Juniperus communis, Carex vitilis, Carex concolor, Epilobium angustifolium, Kalmia glauca, Melampyrum latifolium, Rhinanthus crista-galli* and some others. This leaves 60 species which certainly make up 99 percent. of the vegetation above timber line.

In sorting these into the Raunkiær[40] growth-form categories all woody plants, because of their dwarf habit, have been classed as nanophanerophytes, except those that would naturally go in with the chamaephytes. It may be objected that the fir, black spruce, paper birch, and *Sorbus scopulina* are trees and should consequently go in categories calling for greater stature than nanophanerophytes. The best answer to this is that on the open summit outside of sheltered depressions they are never over 3 feet, and usually flattened against the ground. The flora above timber line, so far as the growth forms are concerned appears to be separable as follows:

Nanophanerophytes	13	or	21.66	percent.
Chamaephytes	9	or	15	percent.
Hemicryptophytes	29	or	48.33	percent.
Geophytes	9	or	15	percent.

As these figures and percentages are of value only in comparison with other regions, and only thus do they indicate response of plants to varying environments, the following table is submitted.

It will be seen from this that the vegetation on the top of Marcy is much like that on the Labrador Coast or in Spitzbergen, notably in the failure of trees of any height to develop, and in the high percentage of perennial herbs. It would be an interesting study to determine, as one of the authors has done for Long Island, N. Y., how these percentages would be effected by considering individuals rather than species. All that could be considered with the time at our disposal were the species, but a more extended study would no doubt result in changes if only the species which make up the bulk of the flora of the summit, were the ones considered.

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[40] Fuller, G. D., and Bakke, A. L. "Raunkiær's Life-forms, Leaf-size Classes and Statistical Methods." Plant World, Vol. 21, pp. 25–37, 1918.

Smith, W. G. "Raunkiær's Life-forms and Statistical Methods." Jour. Ecol., Vol. 1, pp. 16–26, 1913.

TABLE 7. *Biological spectrum of the flora above timber line on Mt. Marcy, as illustrated by Raunkiær's growth-forms, in percentages. (The normal spectrum, and other regions included for comparison.)*

Type of growth form	MG	MS	MC	N	CH	H	G	HH	T
Normal spectrum.........	6		17	20	9	27	3	1	13
Flora of vicinity of N. Y....	.52	4.03	7.18	3.51	5.29	33.29	20.23	11.74	13
Flora of vicinity of N. Y. Northern element of it only..................		1.31	3.94	8.55	8.55	26.31	24.32	23	3.94
400 commonest species on L. I., N. Y............	1.50	3.00	8.50	4.25	7.25	30.00	21.00	6.75	14.25
Baffin's Land............				1.00	30.00	51.00	13.00	3.00	2.00
Iceland.................				2.00	13.00	54.00	10.00	10.00	11.00
Spitzbergen..............				1.00	22	60.00	13.00	2.00	2.00
Labrador Coast..........		2.00	1.00	8.00	17.00	52.00	9.00	5.00	6.00
Above timber line on Mt. Marcy, N. Y...........				21.66	15.00	48.33	15.00		

The figures given, however, are in line with those from the arctic-alpine regions where the chamaephytes and hemicryptophytes are relatively high in number, In the last five localities of the above table, including the summit of Mt. Marcy, there are practically no trees.

So far as species are concerned, it is not without significance that by leaving out of the count those plants that have come up through the fir forest to the summit, we find the remaining element of the vegetation, which may be considered certainly as alpine or sub-alpine to consist of:

N—6, CH—9, H—14, G—-.

While the element that has come up from below and seems an obvious encroachment into the alpine zone consists of:

N—8, CH—-, H—15, G—9.

No attempt has been made to give growth-form percentages from the station *a* at the 4,250 ft. elevation. If *species* were considered here the fir would only figure as one, while if individuals were reckoned it would show 85 percent. of the forest as fir. In nearly exclusive forests of the sort, the Raunkiær growth-form percentages may obscure, rather than elucidate, the truth about vegetative response to climate, while in the alpine zone they give interesting comparisons with the flora of other parts of the world.

VIII. SUMMARY AND CONCLUSION

The methods of study and viewpoints of zoologists, botanists, and foresters have been brought together for a brief cooperative study of the factors